US011885526B2

(12) United States Patent
Thobias et al.

(10) Patent No.: US 11,885,526 B2
(45) Date of Patent: Jan. 30, 2024

(54) HIGH-PERFORMANCE HOUSINGS FOR BACKWARD-CURVED BLOWERS

(71) Applicant: **Lennox Industries Inc.**, Richardson, TX (US)

(72) Inventors: **Patric Ananda Balan Thobias**, Chennai (IN); **Amit Parsai**, Chennai (IN); **Shiliang Wang**, Carrollton, TX (US)

(73) Assignee: **Lennox Industries Inc.**, Richardson, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 293 days.

(21) Appl. No.: **17/230,037**

(22) Filed: **Apr. 14, 2021**

(65) **Prior Publication Data**

US 2022/0333799 A1 Oct. 20, 2022

(51) **Int. Cl.**

F24F 7/06	(2006.01)
F24F 13/20	(2006.01)
F24F 7/007	(2006.01)
F24F 7/08	(2006.01)
F24F 11/74	(2018.01)
F04D 25/08	(2006.01)
F04D 29/28	(2006.01)
F04D 29/42	(2006.01)

(52) **U.S. Cl.**

CPC ***F24F 7/06*** (2013.01); ***F04D 25/08*** (2013.01); ***F04D 29/282*** (2013.01); ***F04D 29/4226*** (2013.01); ***F24F 7/007*** (2013.01); ***F24F 7/08*** (2013.01); ***F24F 11/74*** (2018.01); ***F24F 13/20*** (2013.01); *F24F 2013/205* (2013.01)

(58) **Field of Classification Search**

CPC .. F04D 29/4226; F24F 13/20; F24F 2013/205

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,857,747 A *	10/1958	MacCracken	F24F 3/0442	62/428
2005/0042107 A1*	2/2005	Liu	F04D 29/282	416/206

FOREIGN PATENT DOCUMENTS

EP	2336574 A1 *	6/2011	F04D 29/4226	

* cited by examiner

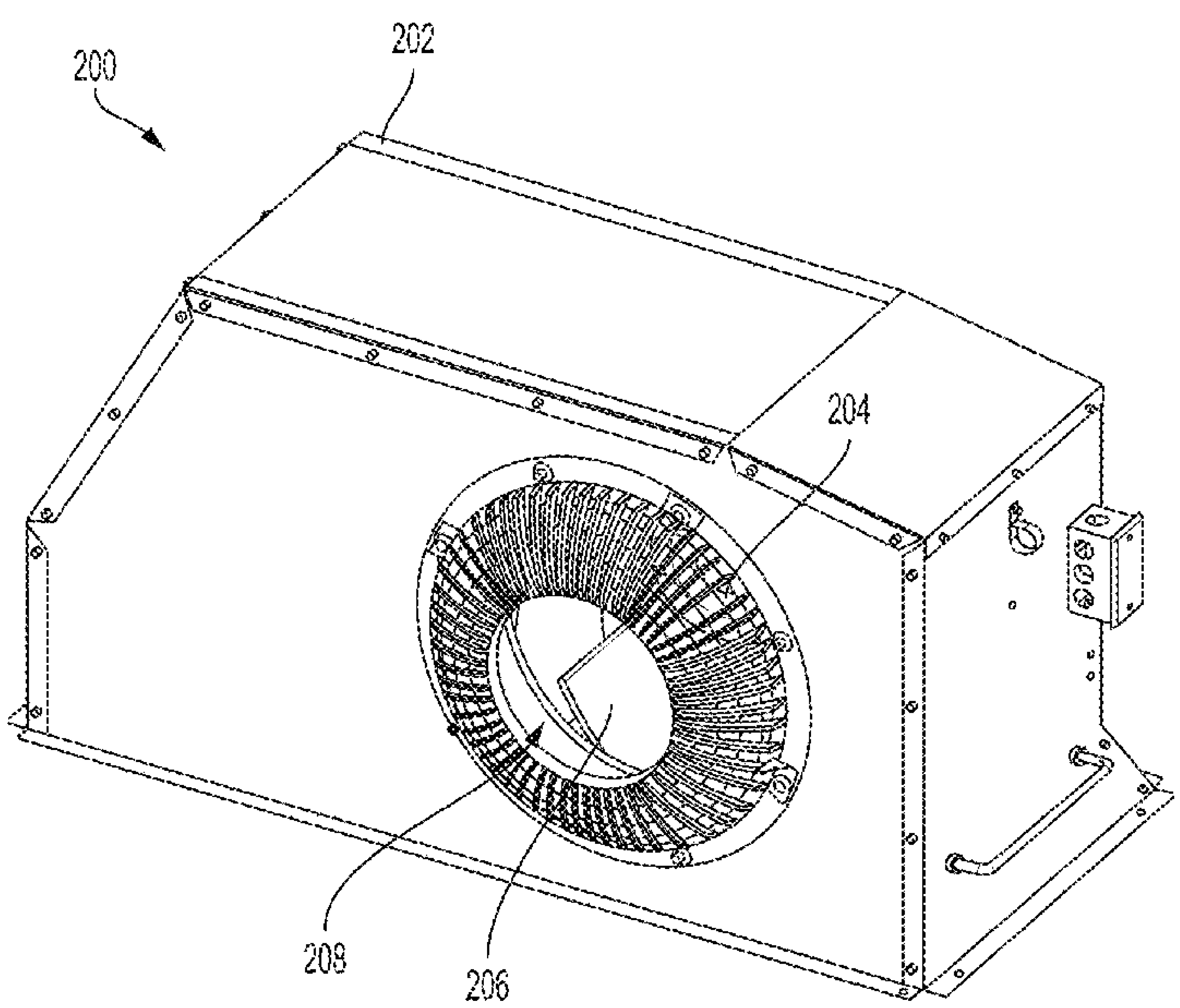
Primary Examiner — Brian O Peters

(74) *Attorney, Agent, or Firm* — Bradley Arant Boult Cummings

(57) **ABSTRACT**

In an embodiment, a blower for a heating, ventilation, and air conditioning system includes a blower wheel and a housing. The blower wheel includes backward-curved blades configured to rotate in a rotational plane. The housing forms an at least hexagonal cross- section around at least a portion of the rotational plane, where the blower wheel is positioned within the housing such that there exists a first distance and a second distance. The first distance is measured radially outward from a center of the blower wheel to a first side of the at least hexagonal cross-section. The second distance is measured radially outward from the center of the blower wheel to a second side of the at least hexagonal cross-section. The second distance forms a an acute angle with the first distance. The first distance and the second distance are unequal and less than a diameter of the blower wheel.

16 Claims, 14 Drawing Sheets



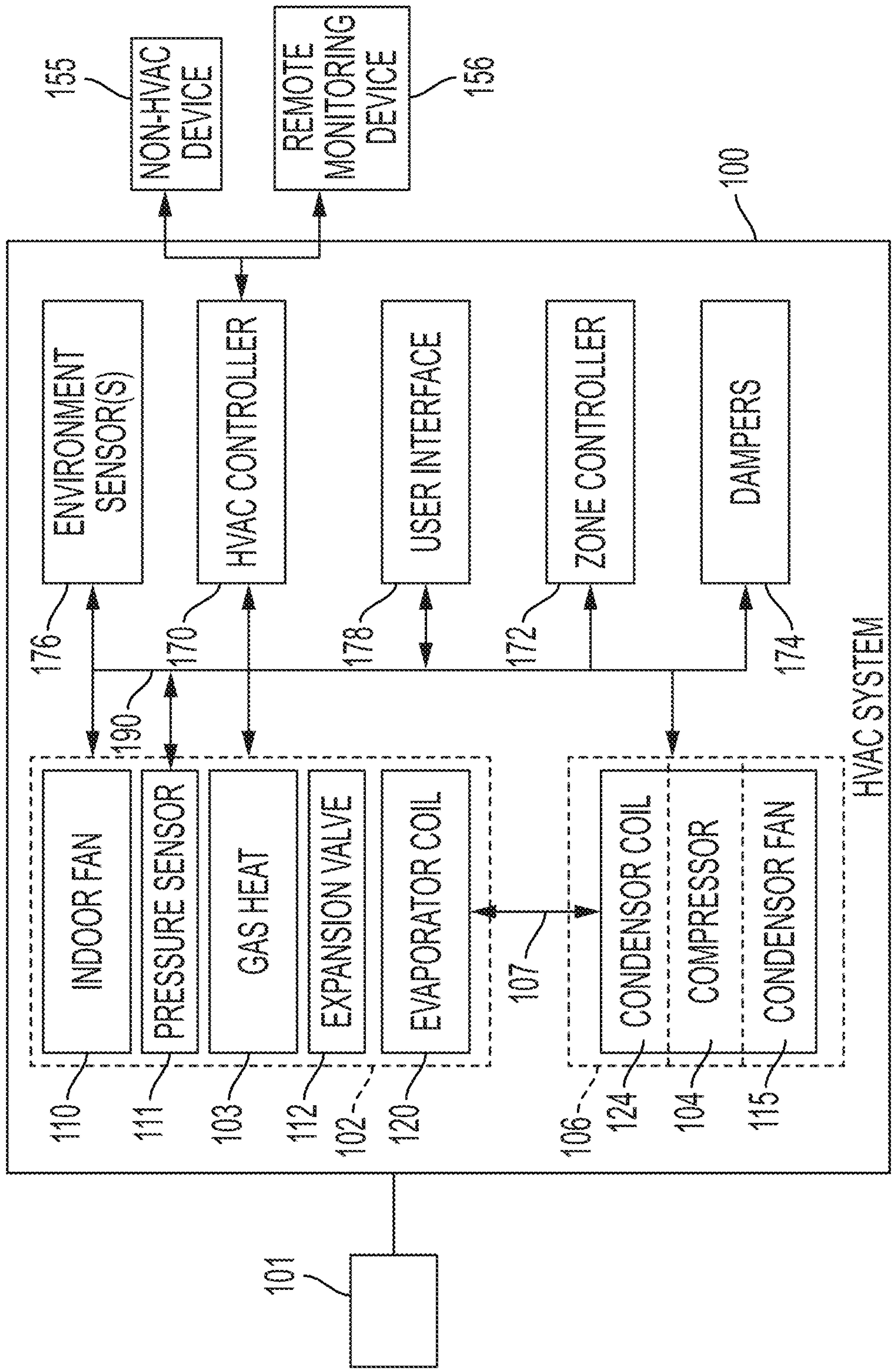

NON-HVAC DEVICE
155
REMOTE MONITORING DEVICE
156
100
ENVIRONMENT SENSOR(S)
176
HVAC CONTROLLER
170
USER INTERFACE
178
ZONE CONTROLLER
172
DAMPERS
174
190
INDOOR FAN
110
PRESSURE SENSOR
111
GAS HEAT
103
EXPANSION VALVE
112
102
EVAPORATOR COIL
120
107
CONDENSOR COIL
124
COMPRESSOR
104
CONDENSOR FAN
115
106
HVAC SYSTEM
101

FIG. 1

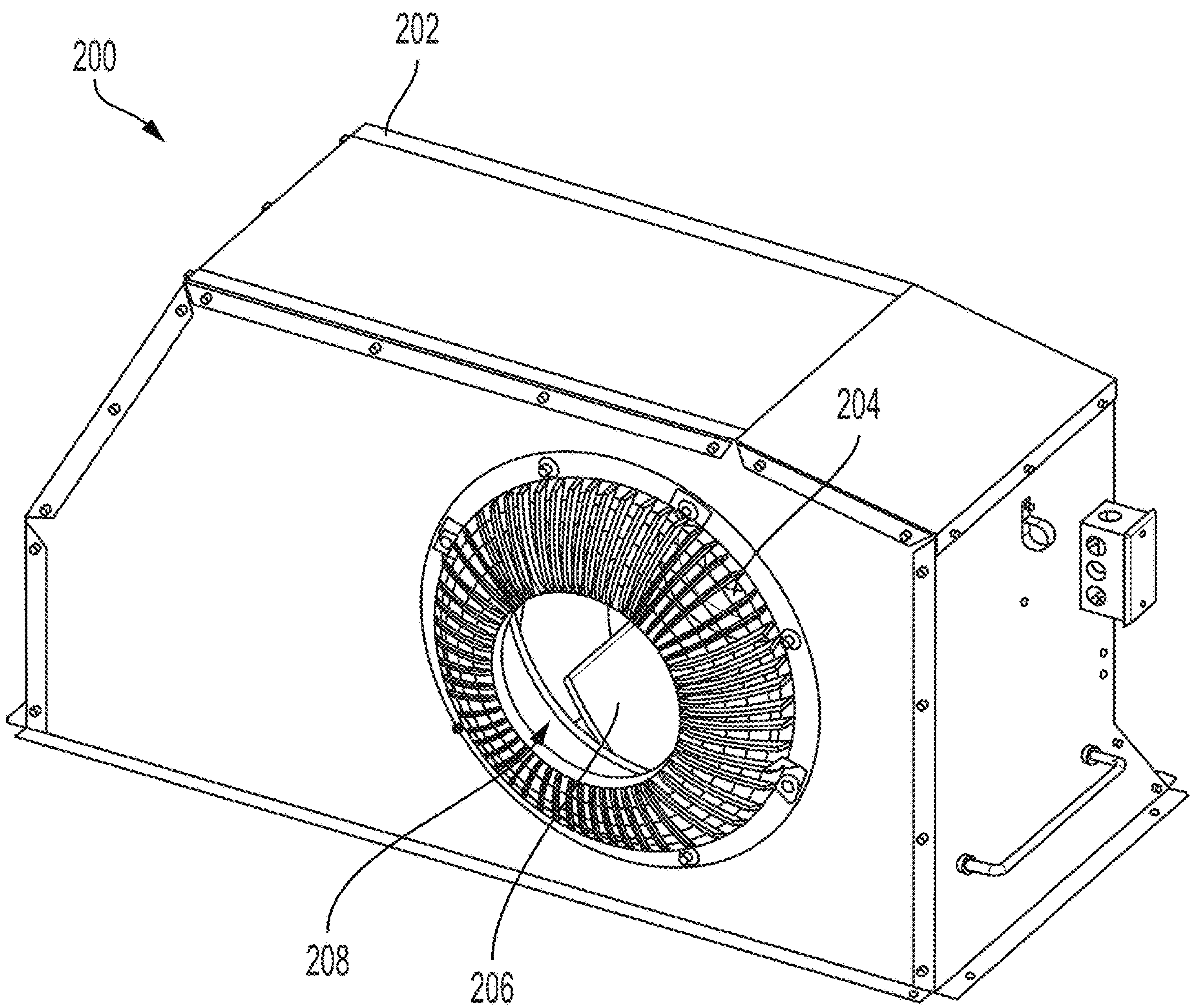


FIG. 2A

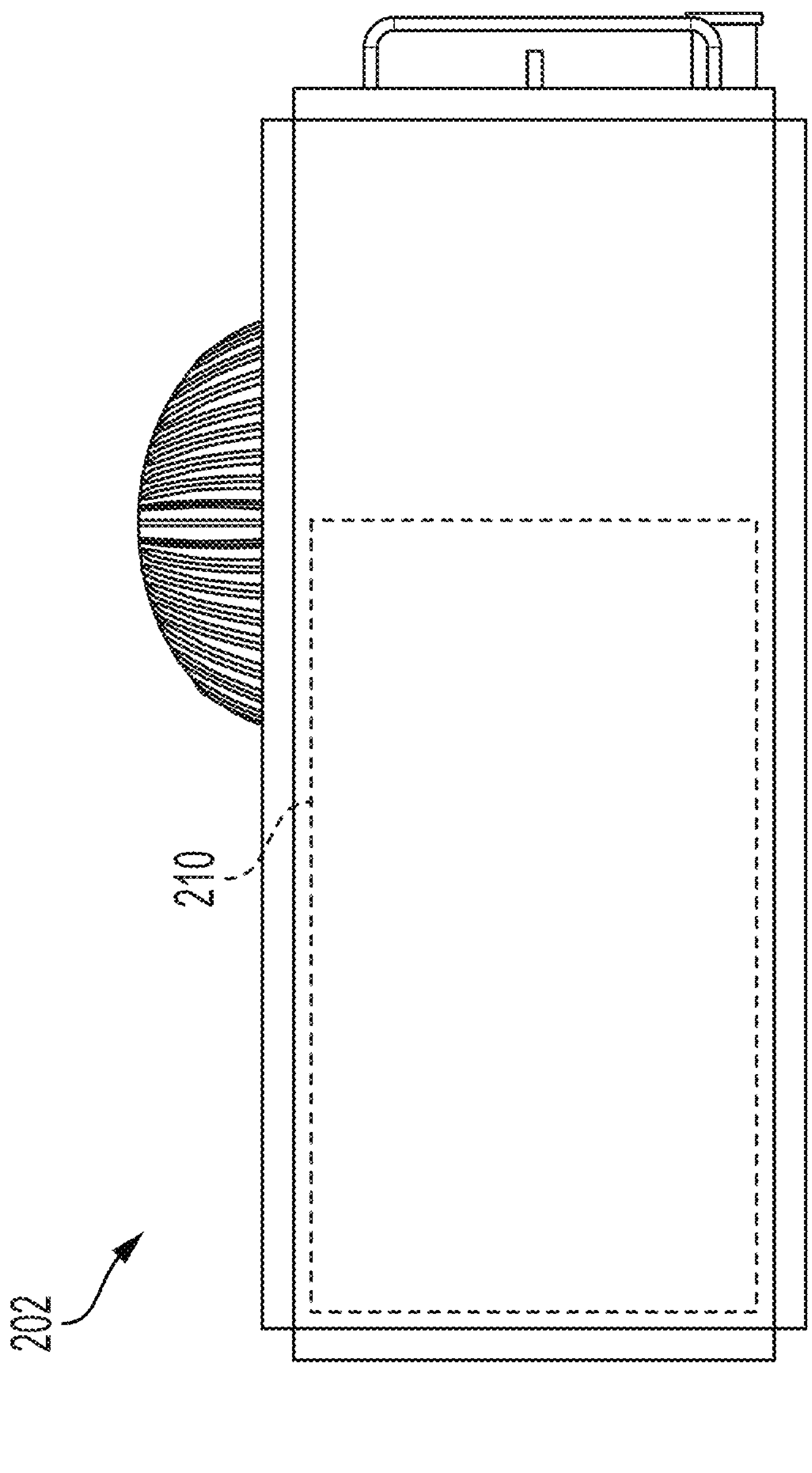


FIG. 2B

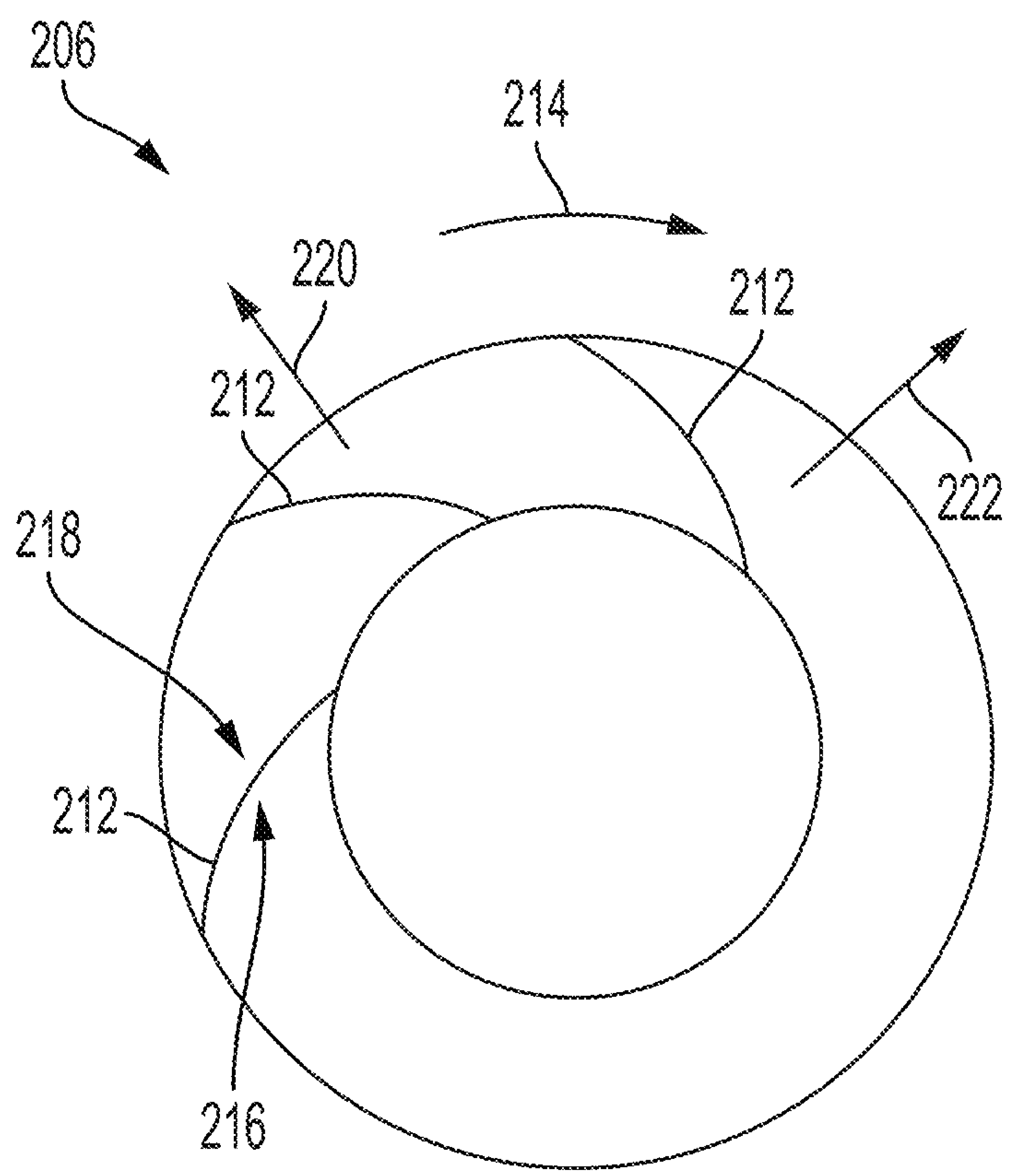


FIG. 2C

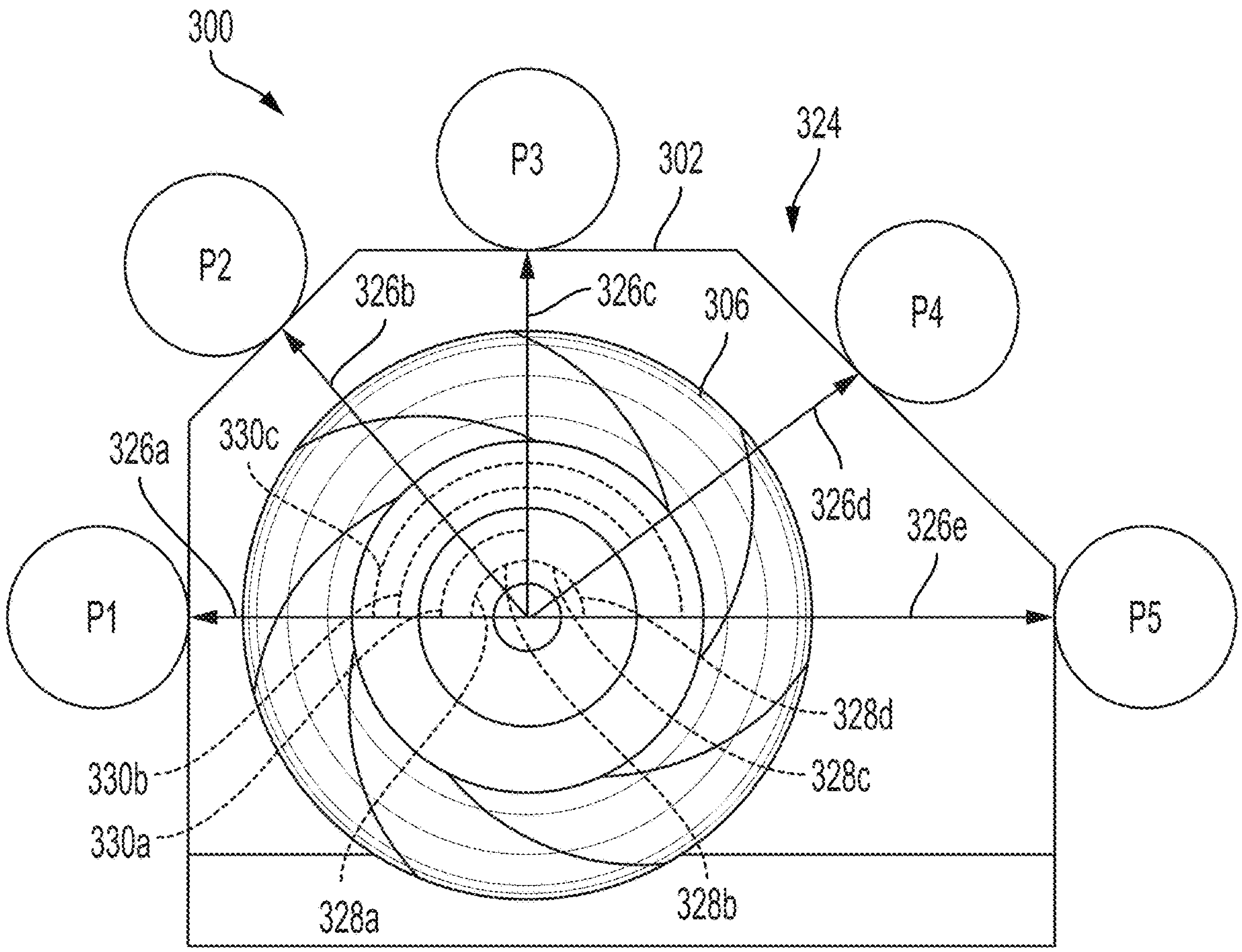

300
324
302
P3
P2
P4
326b
326c
306
326a
330c
326d
326e
P1
P5
328d
330b
328c
330a
328a
328b

FIG. 3

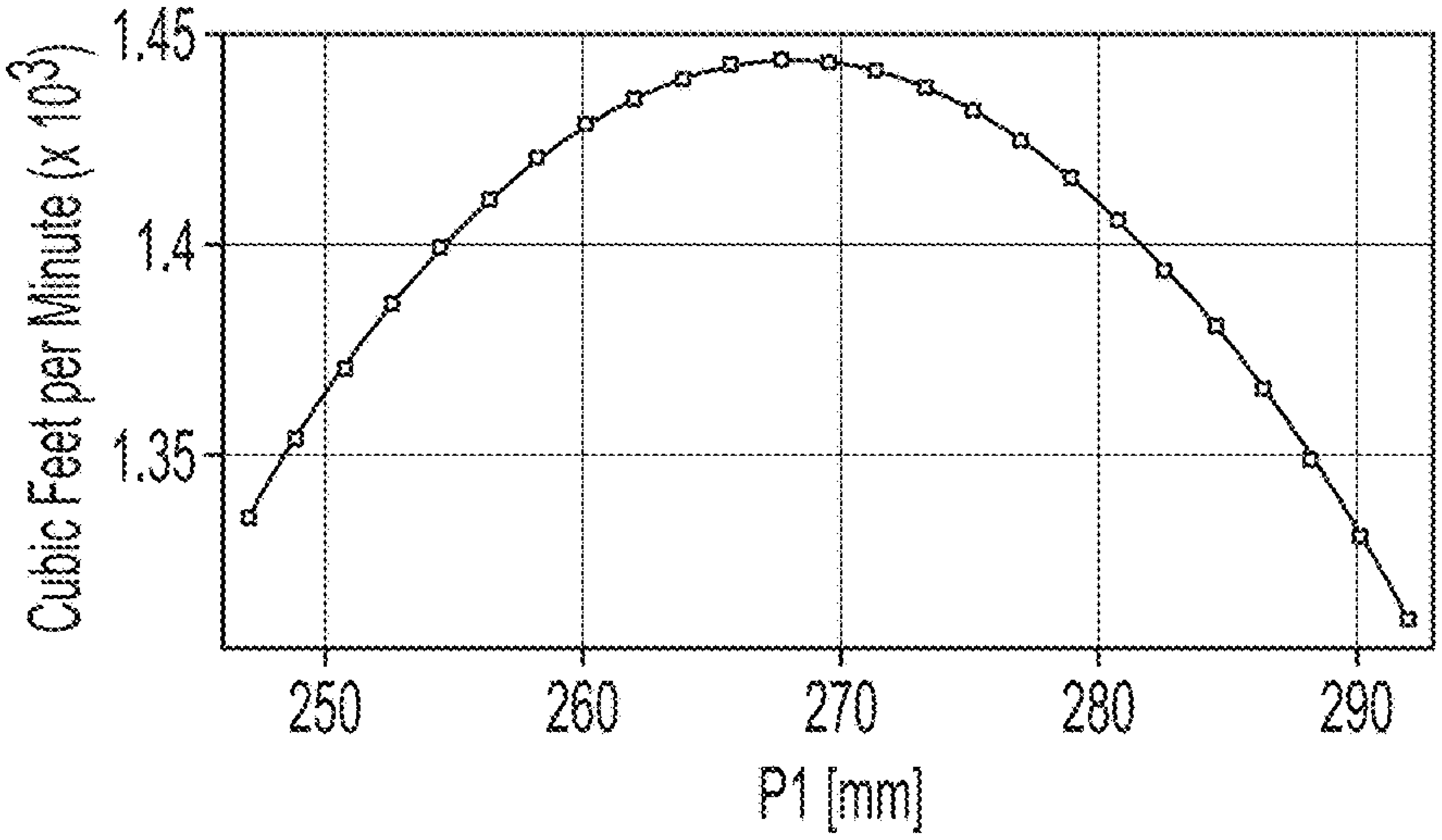


FIG. 4A

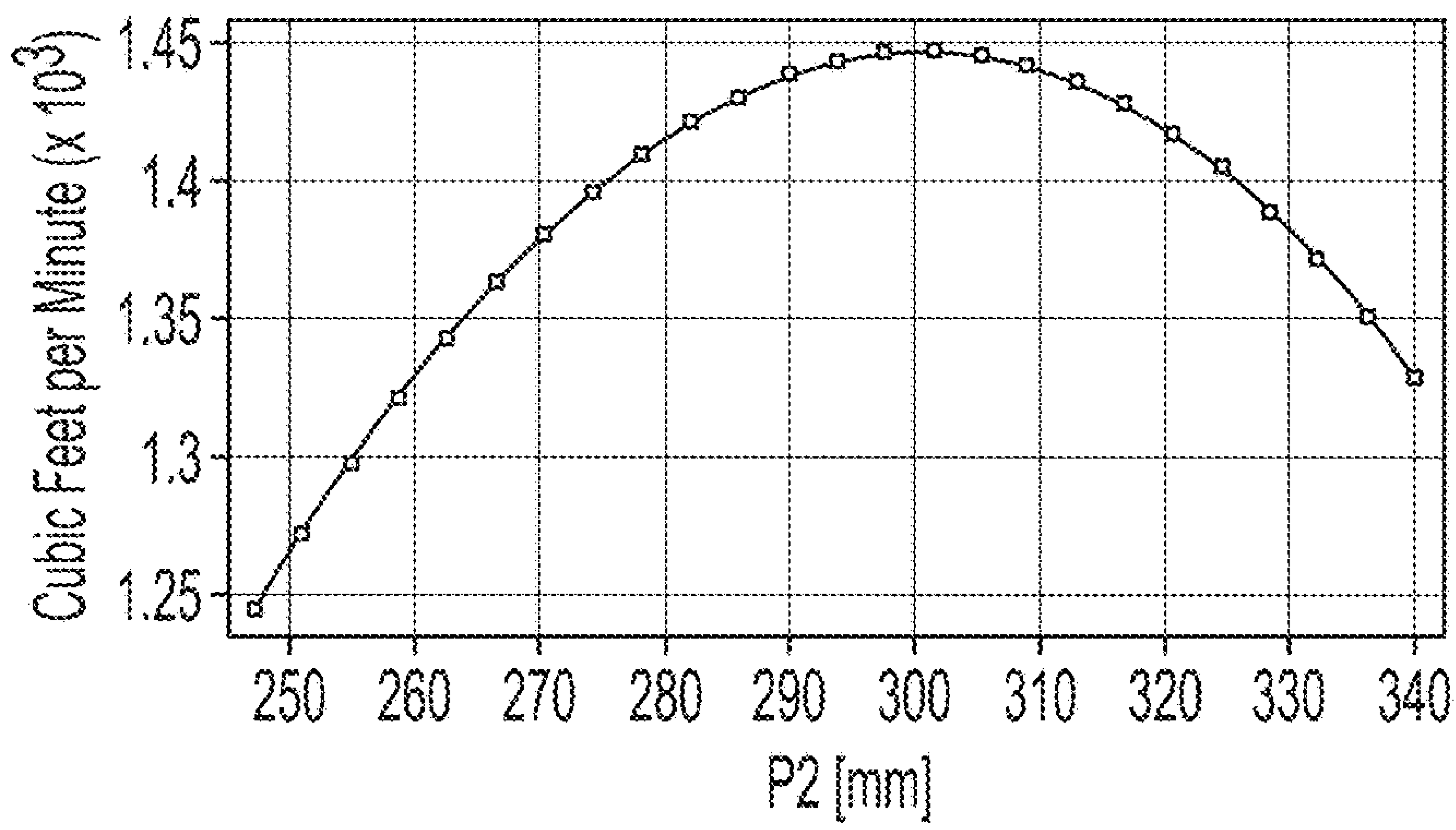


FIG. 4B

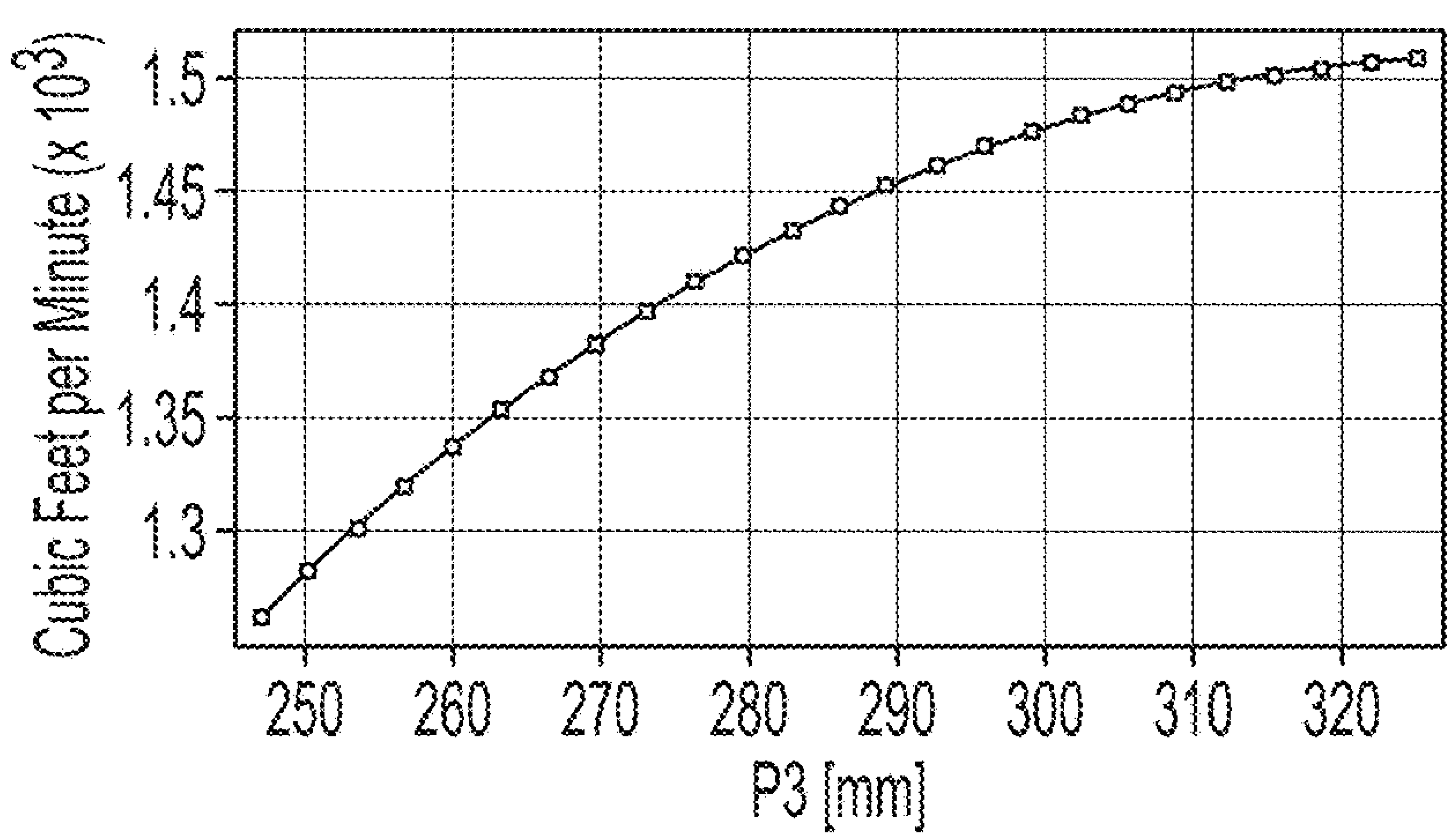


FIG. 4C

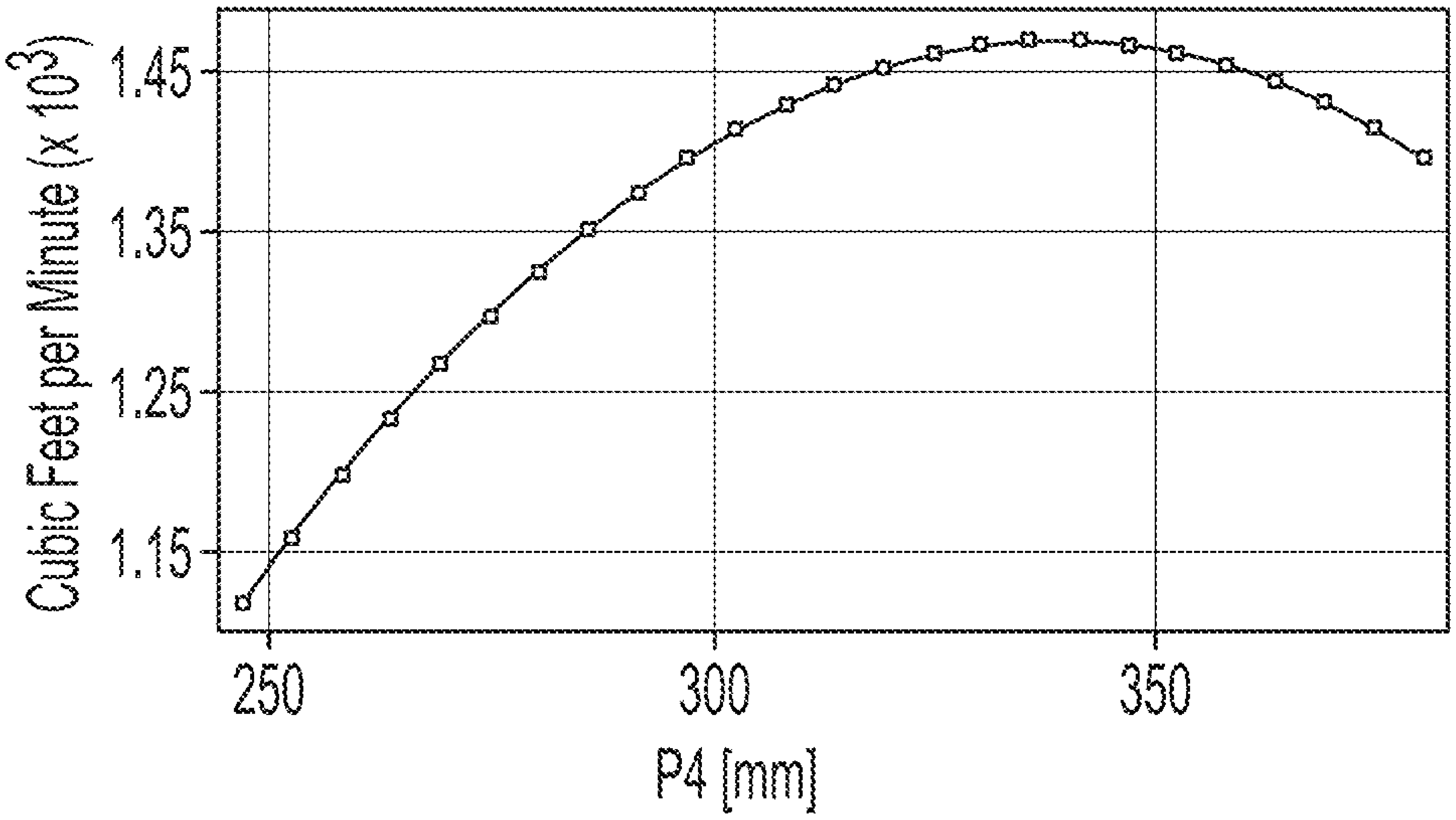

Cubic Feet per Minute (x 10³)
1.45
1.35
1.25
1.15
250
300
350
P4 [mm]

FIG. 4D

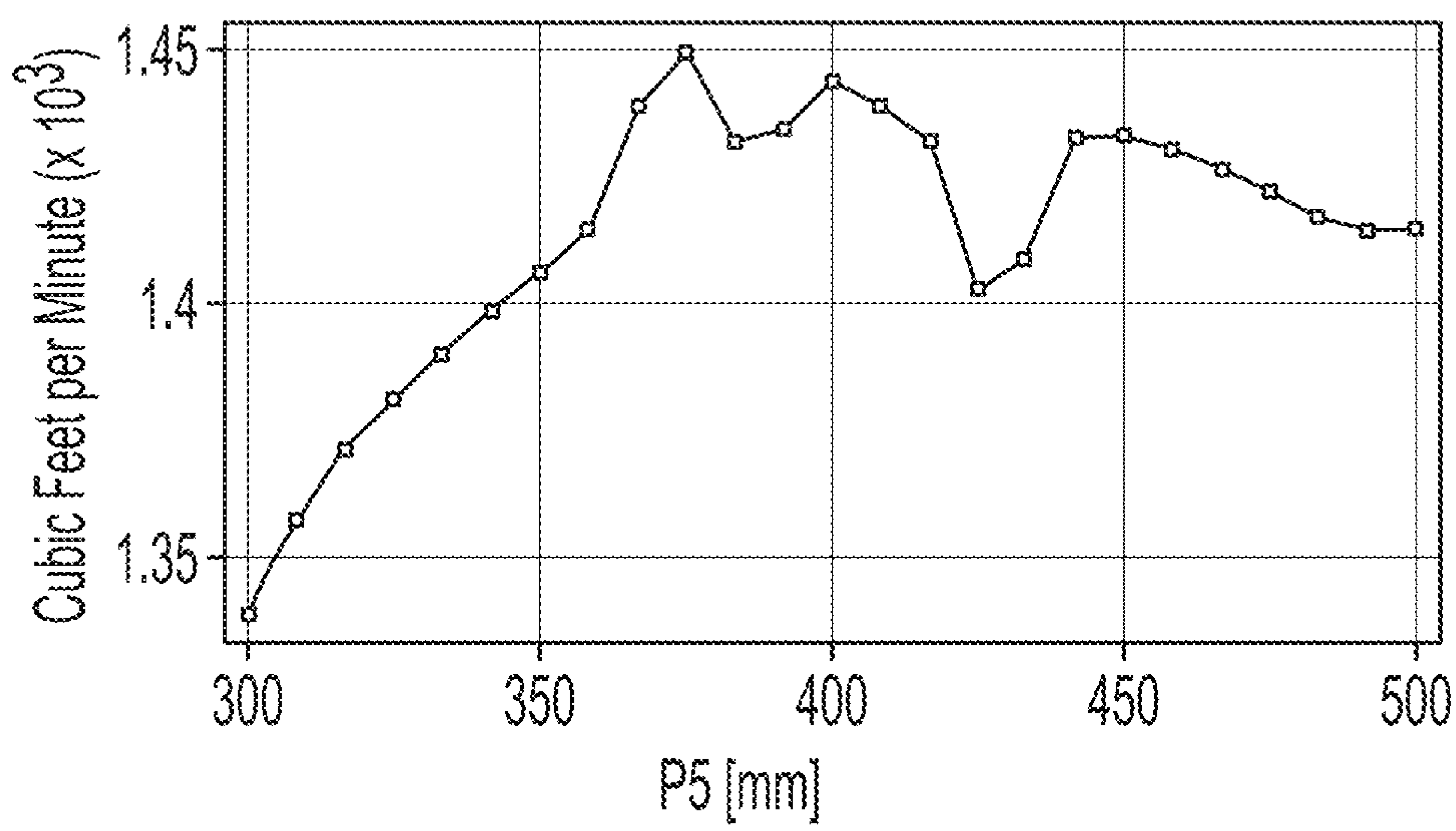

Cubic Feet per Minute (x 10³)
1.45
1.4
1.35
300
350
400
450
500
P5 [mm]

FIG. 4E

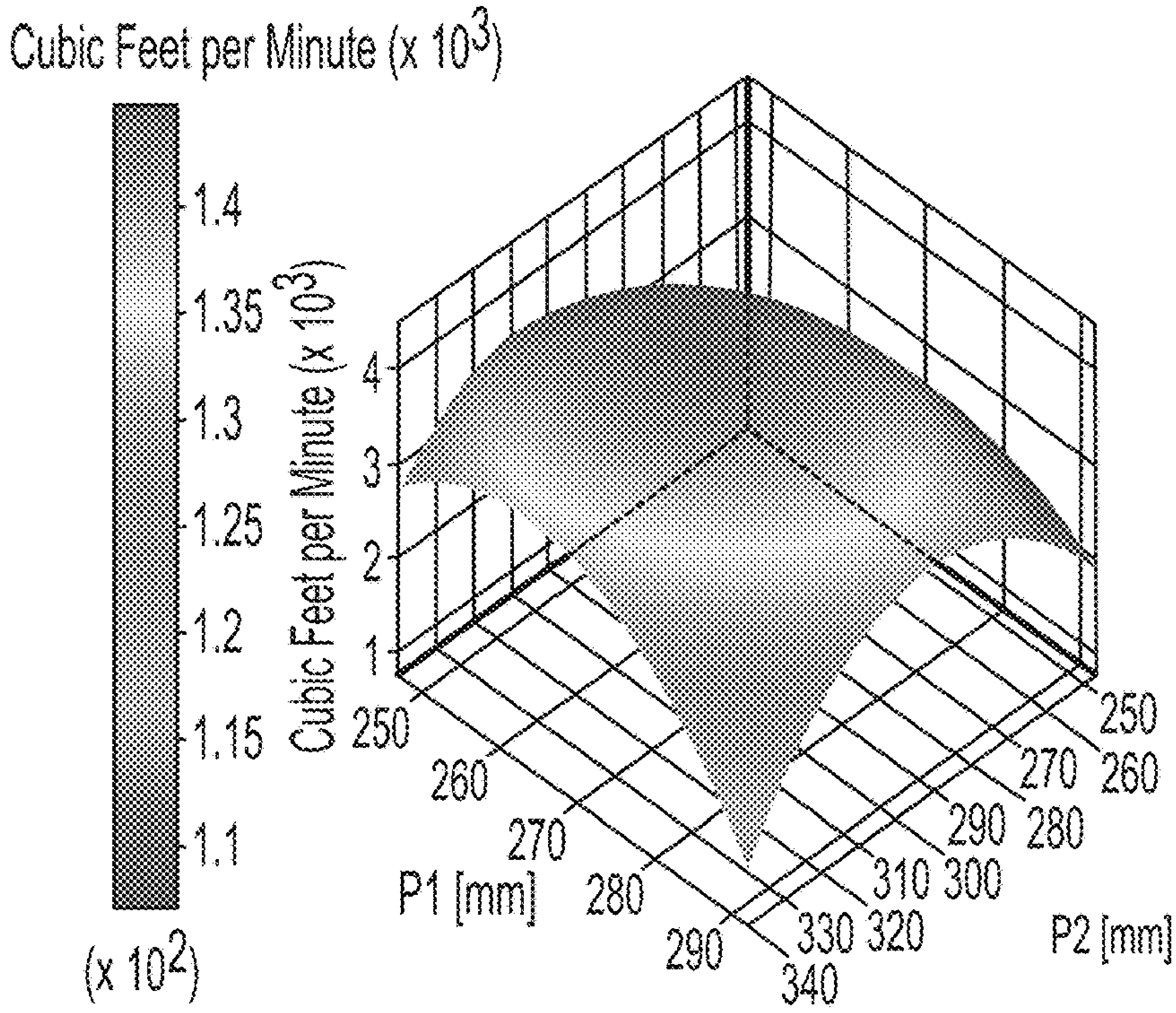

Cubic Feet per Minute (x 10^3)
1.4
1.35
1.3
1.25
1.2
1.15
1.1
(x 10^2)
Cubic Feet per Minute (x 10^3)
4
3
2
1
250
260
270
280
290
P1 [mm]
250
260
270
280
290
300
310
320
330
340
P2 [mm]

FIG. 5A

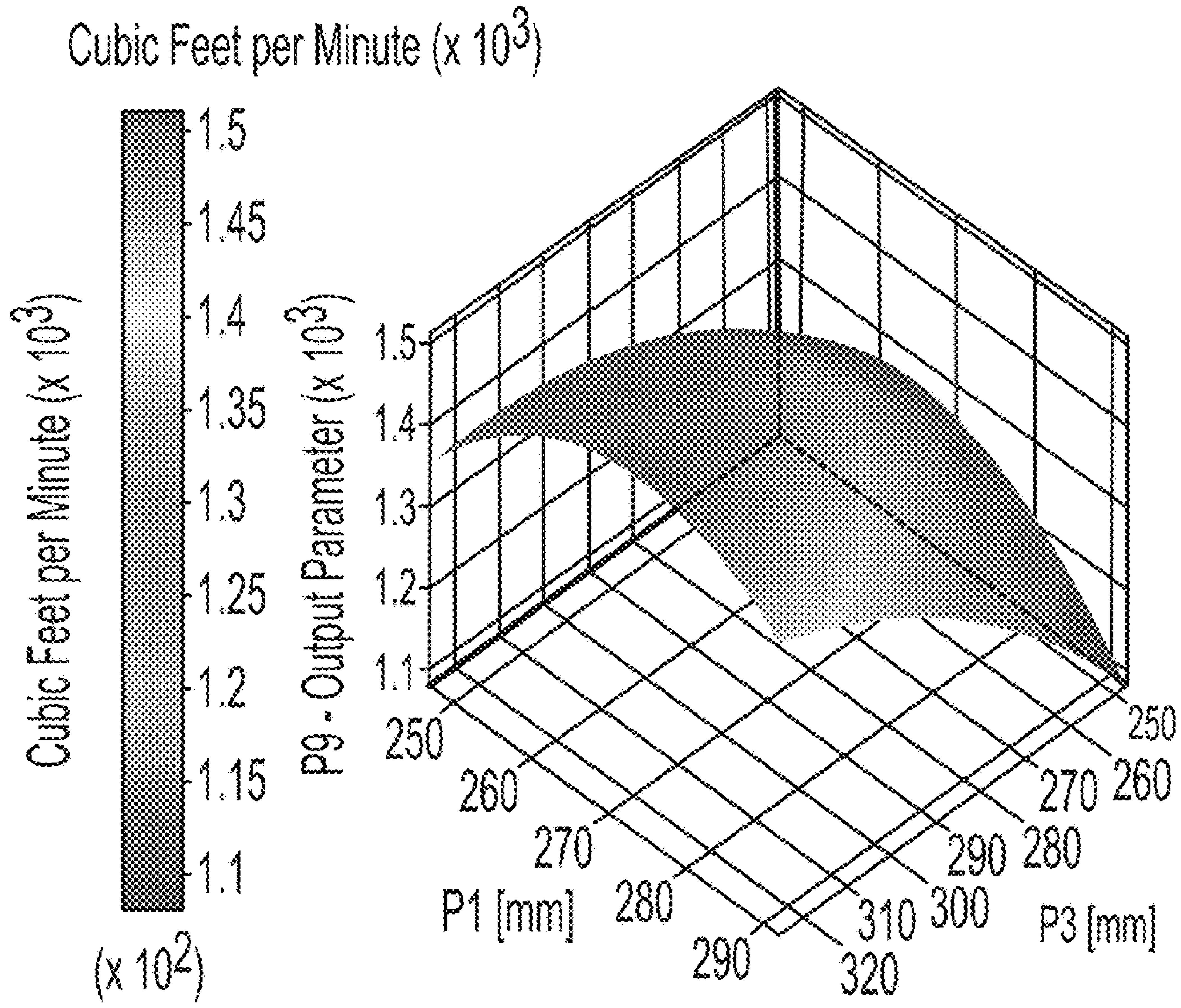

Cubic Feet per Minute (x 10^3)
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
(x 10^2)
Cubic Feet per Minute (x 10^3)
P9 - Output Parameter (x 10^3)
1.5
1.4
1.3
1.2
1.1
250
260
270
280
290
P1 [mm]
250
260
270
280
290
300
310
320
P3 [mm]

FIG. 5B

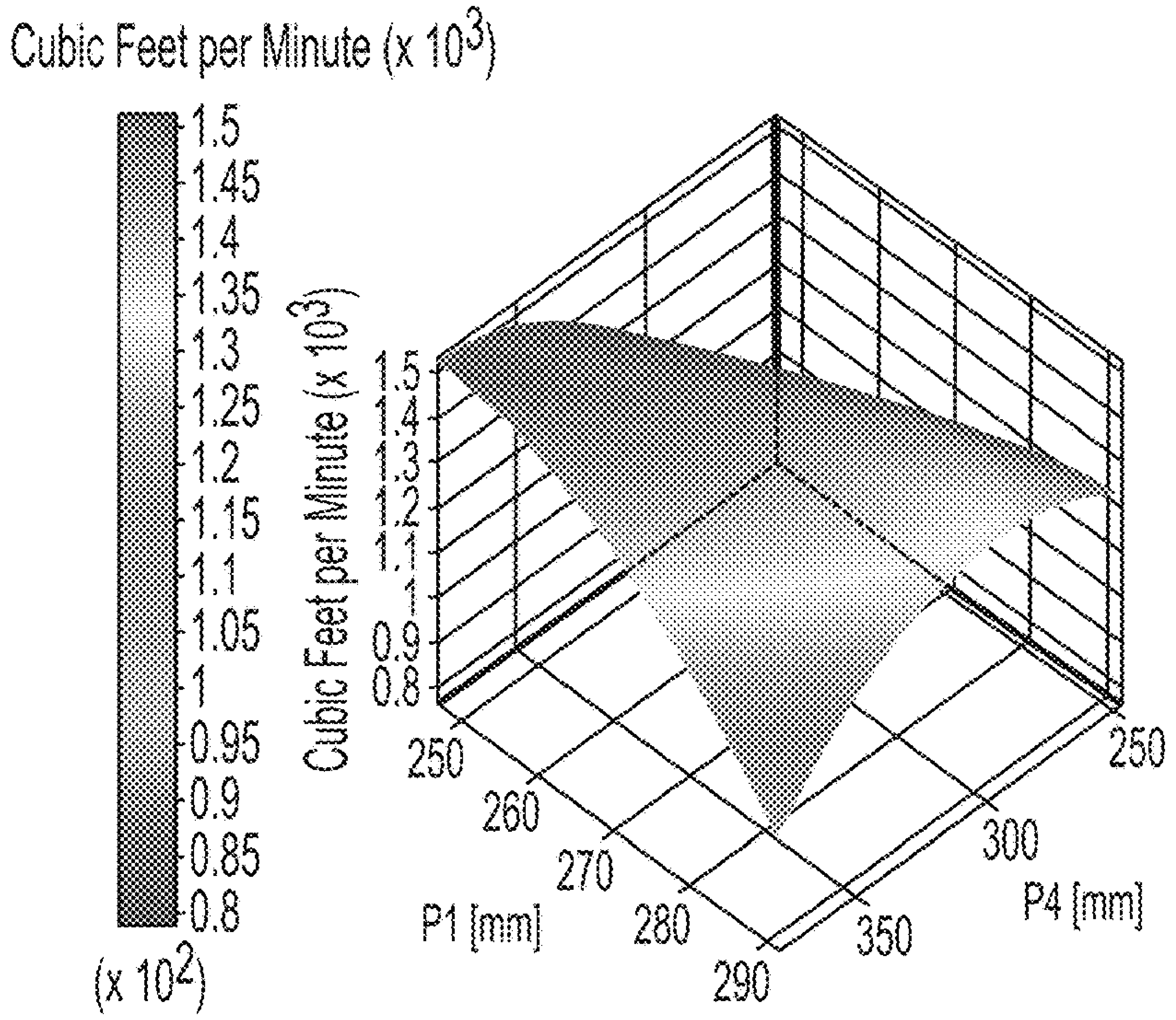

Cubic Feet per Minute (x 10^3)
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
(x 10^2)
Cubic Feet per Minute (x 10^3)
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
250
260
270
280
290
P1 [mm]
250
300
350
P4 [mm]

FIG. 5C

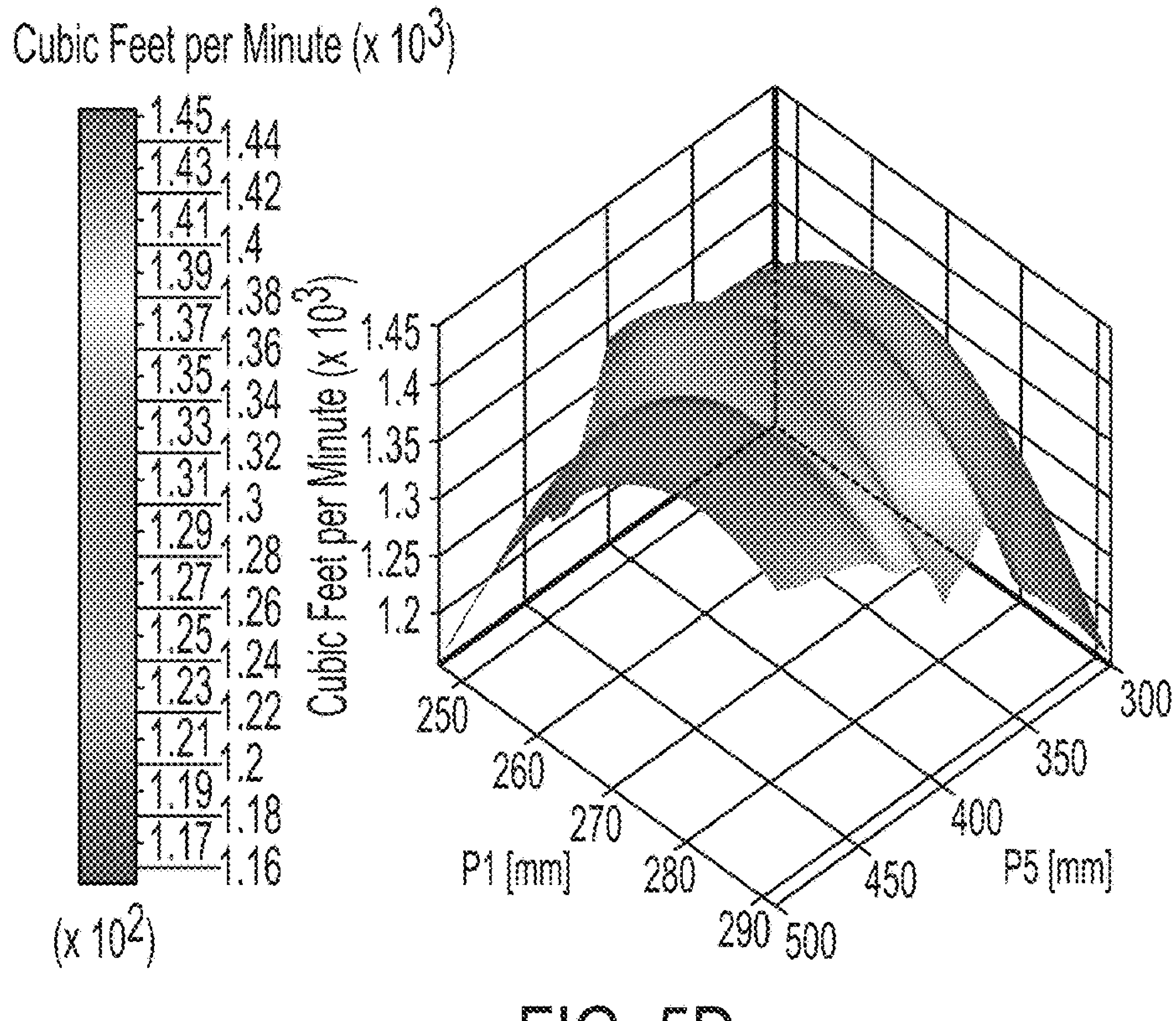

Cubic Feet per Minute (x 10^3)
1.45
1.44
1.43
1.42
1.41
1.4
1.39
1.38
1.37
1.36
1.35
1.34
1.33
1.32
1.31
1.3
1.29
1.28
1.27
1.26
1.25
1.24
1.23
1.22
1.21
1.2
1.19
1.18
1.17
1.16
(x 10^2)
Cubic Feet per Minute (x 10^3)
1.45
1.4
1.35
1.3
1.25
1.2
250
260
270
280
290
P1 [mm]
300
350
400
450
500
P5 [mm]

FIG. 5D

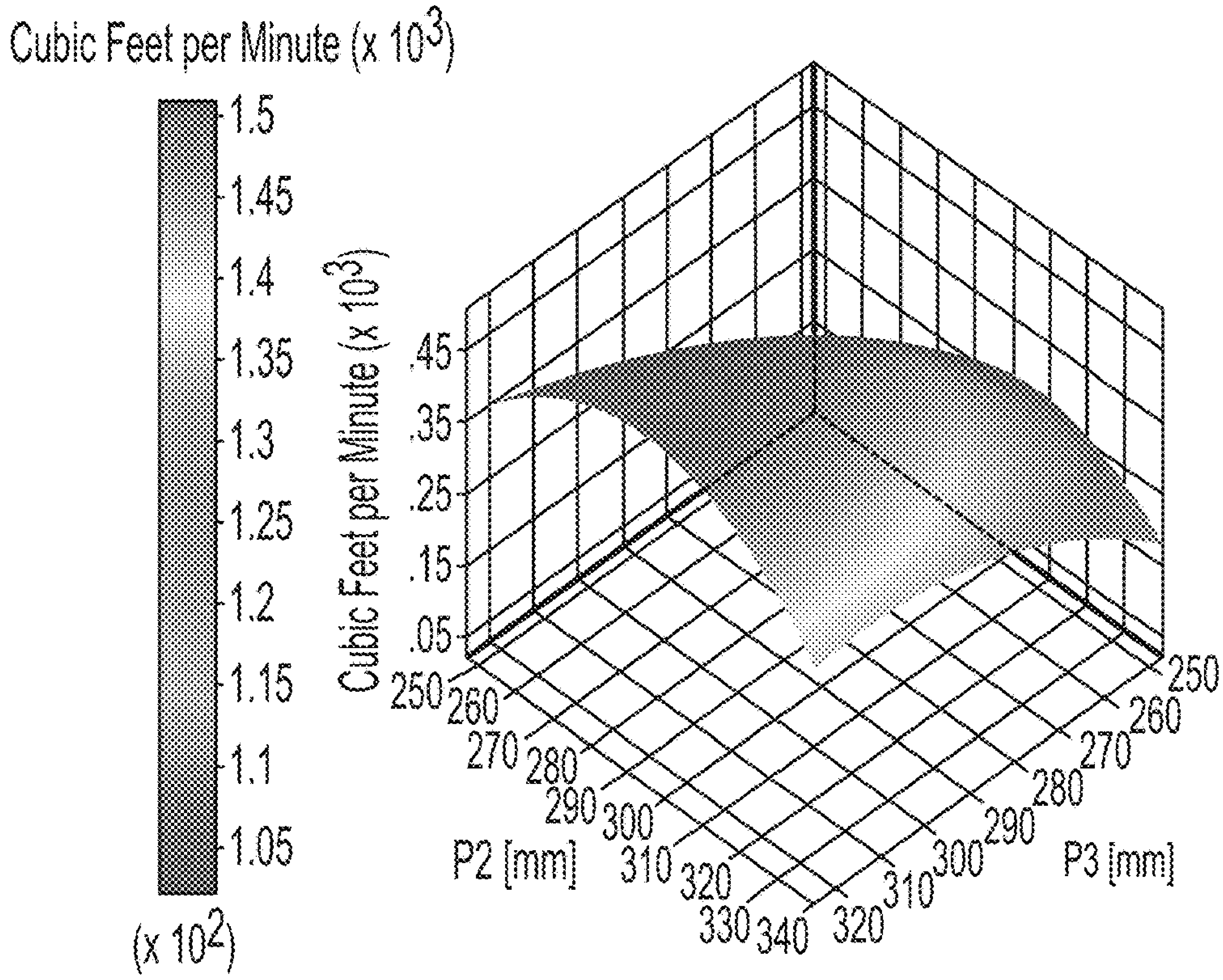

Cubic Feet per Minute (x 10^3)
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
(x 10^2)
Cubic Feet per Minute (x 10^3)
.45
.35
.25
.15
.05
250 260 270 280 290 300 310 320 330 340
P2 [mm]
250 260 270 280 290 300 310 320
P3 [mm]

FIG. 5E

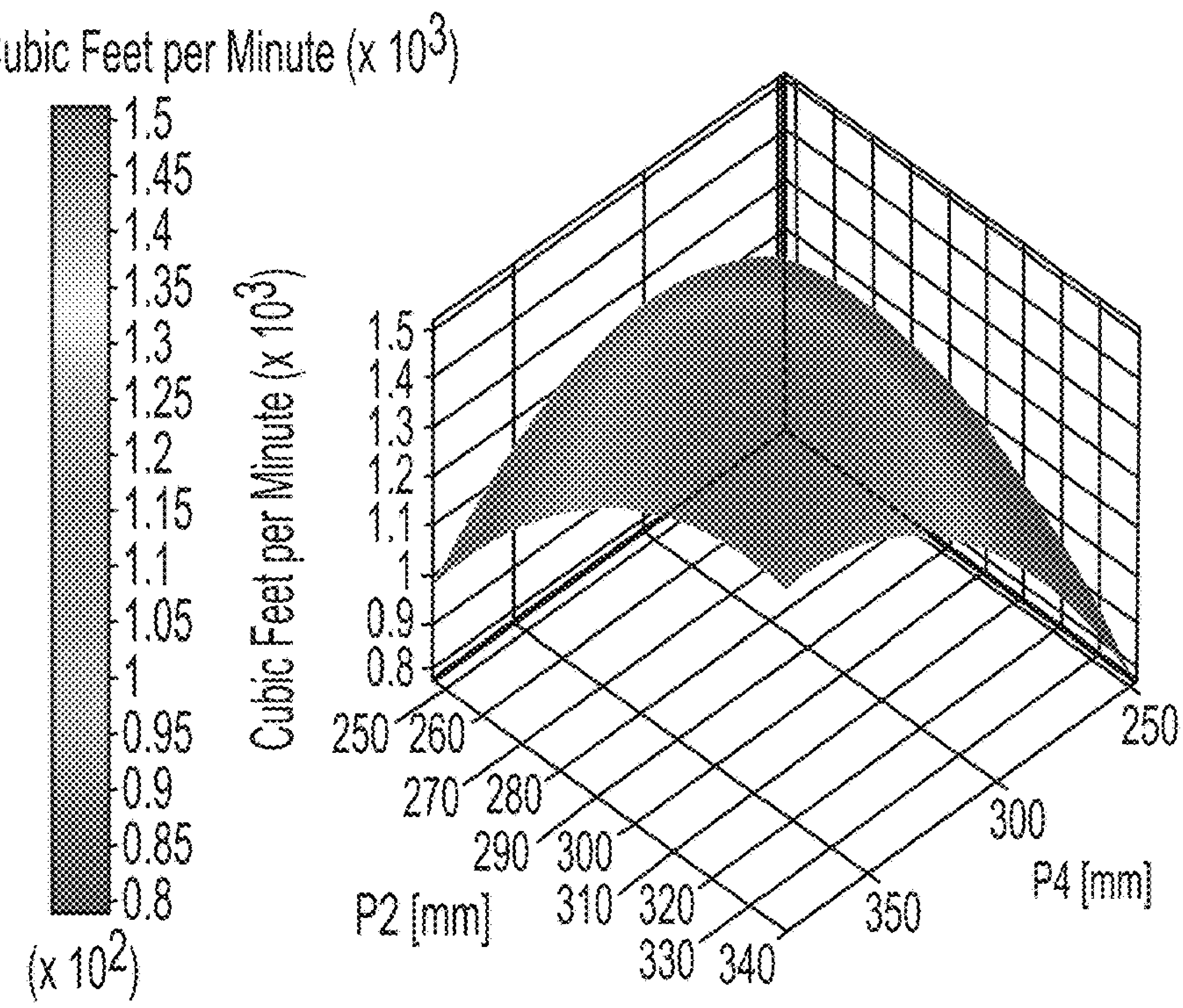

Cubic Feet per Minute (x 10^3)
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
(x 10^2)
Cubic Feet per Minute (x 10^3)
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
250 260 270 280 290 300 310 320 330 340
P2 [mm]
250 300 350
P4 [mm]

FIG. 5F

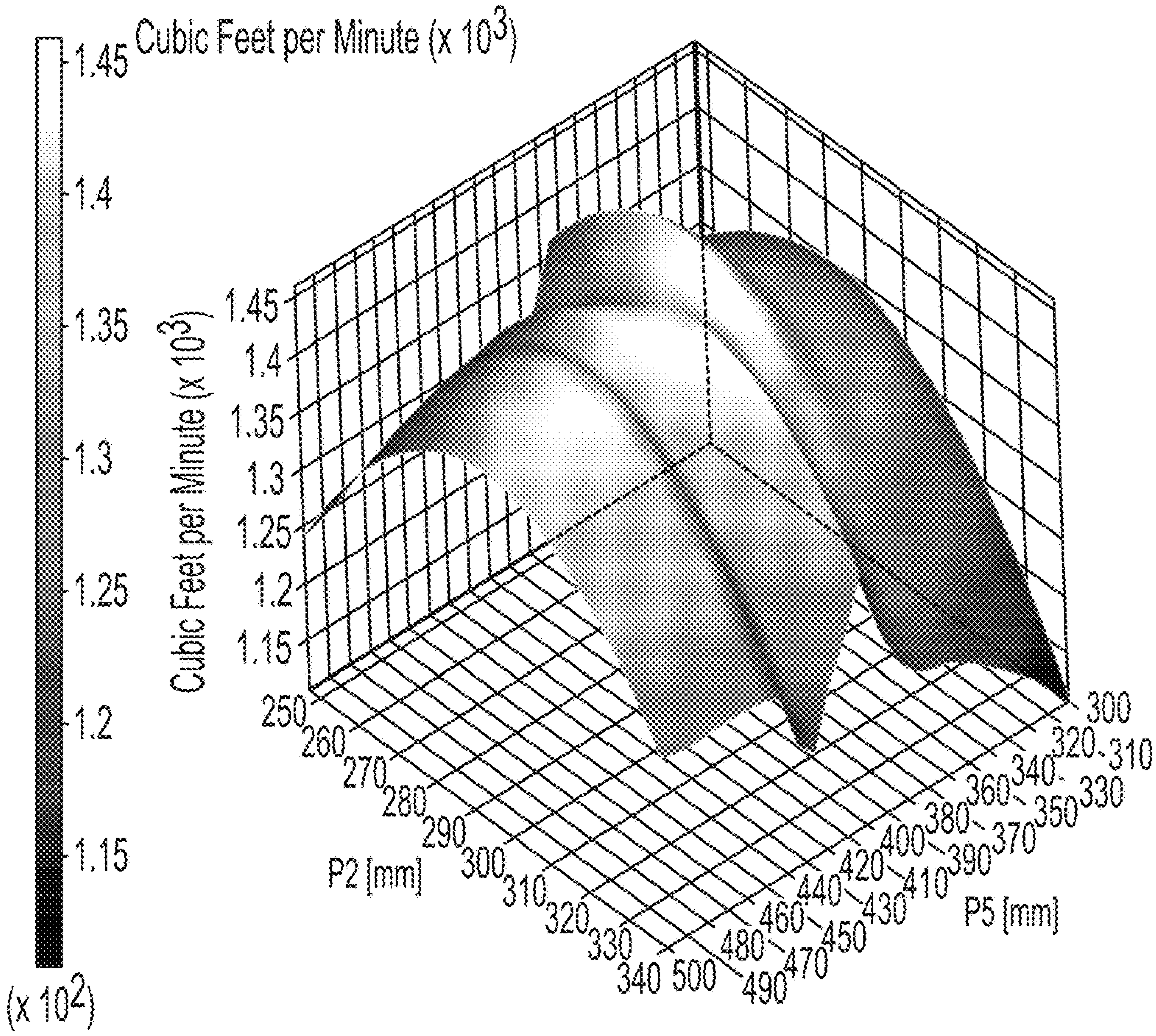

Cubic Feet per Minute (x 10^3)
1.45
1.4
1.35
1.3
1.25
1.2
1.15
(x 10^2)
Cubic Feet per Minute (x 10^3)
P2 [mm]
P5 [mm]

FIG. 5G

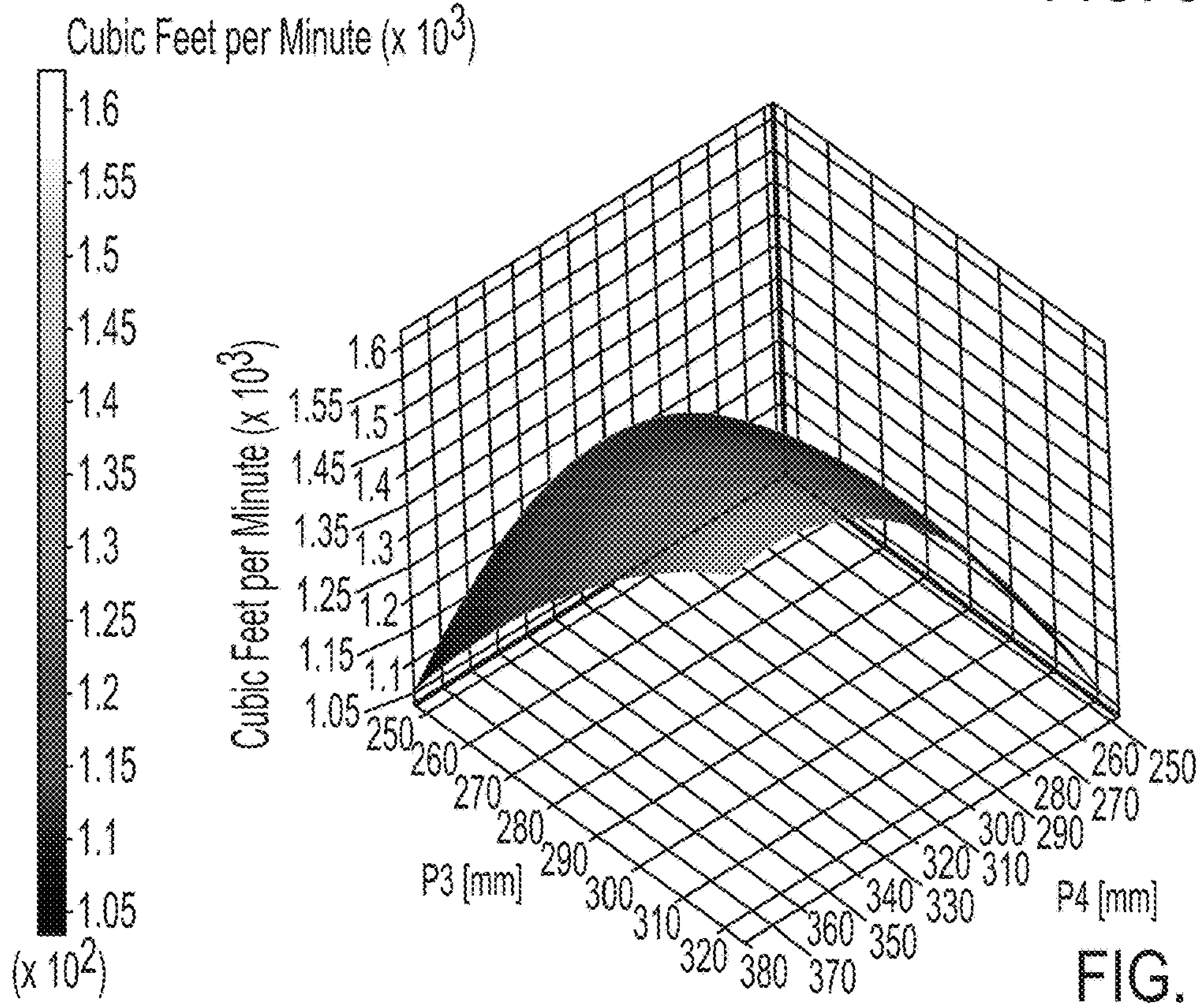

Cubic Feet per Minute (x 10^3)
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
(x 10^2)
Cubic Feet per Minute (x 10^3)
P3 [mm]
P4 [mm]

FIG. 5H

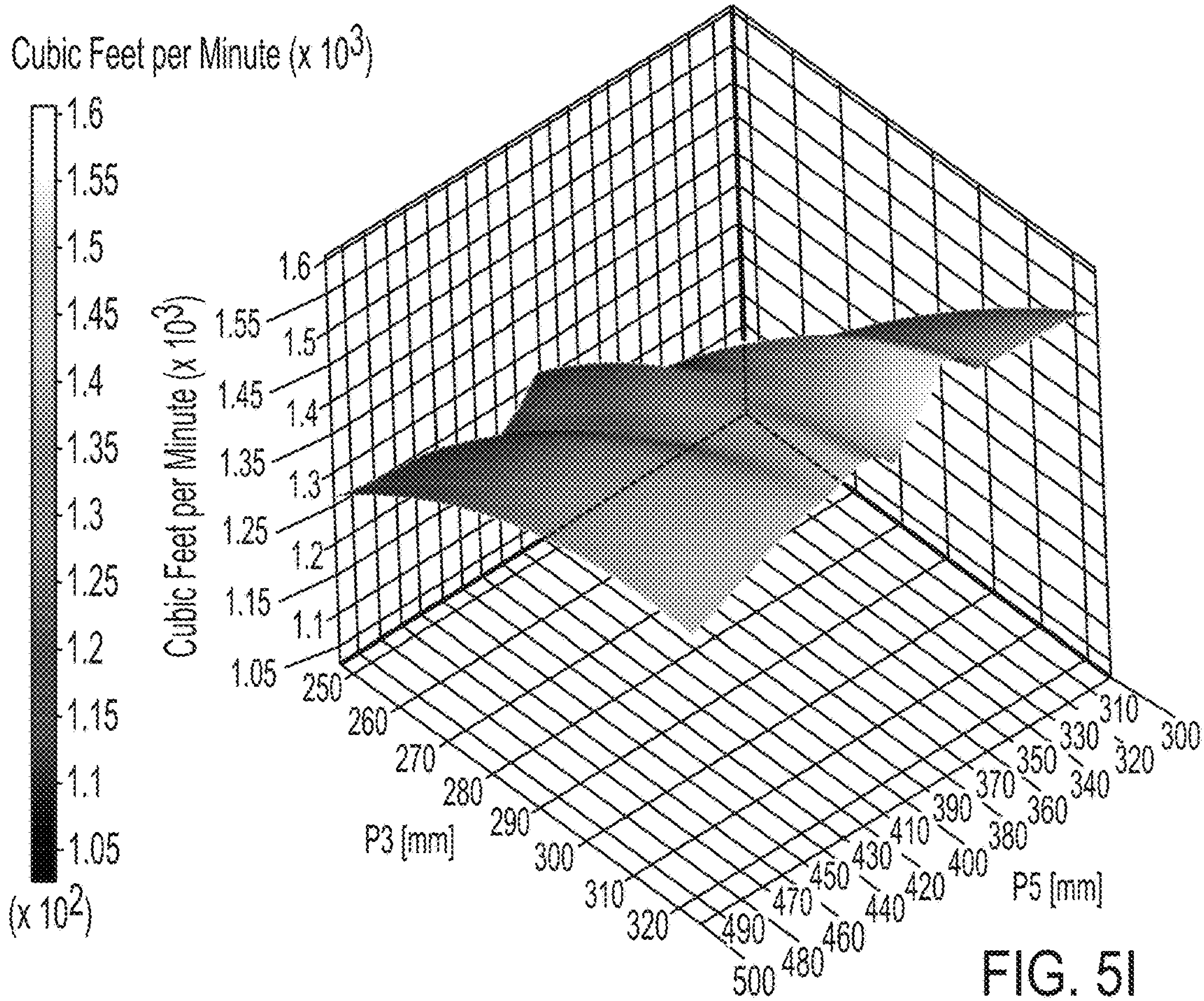

Cubic Feet per Minute (x 10^3)
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
(x 10^2)
Cubic Feet per Minute (x 10^3)
P3 [mm]
250
260
270
280
290
300
310
320
P5 [mm]
300
310
320
330
340
350
360
370
380
390
400
410
420
430
440
450
460
470
480
490
500

FIG. 5I

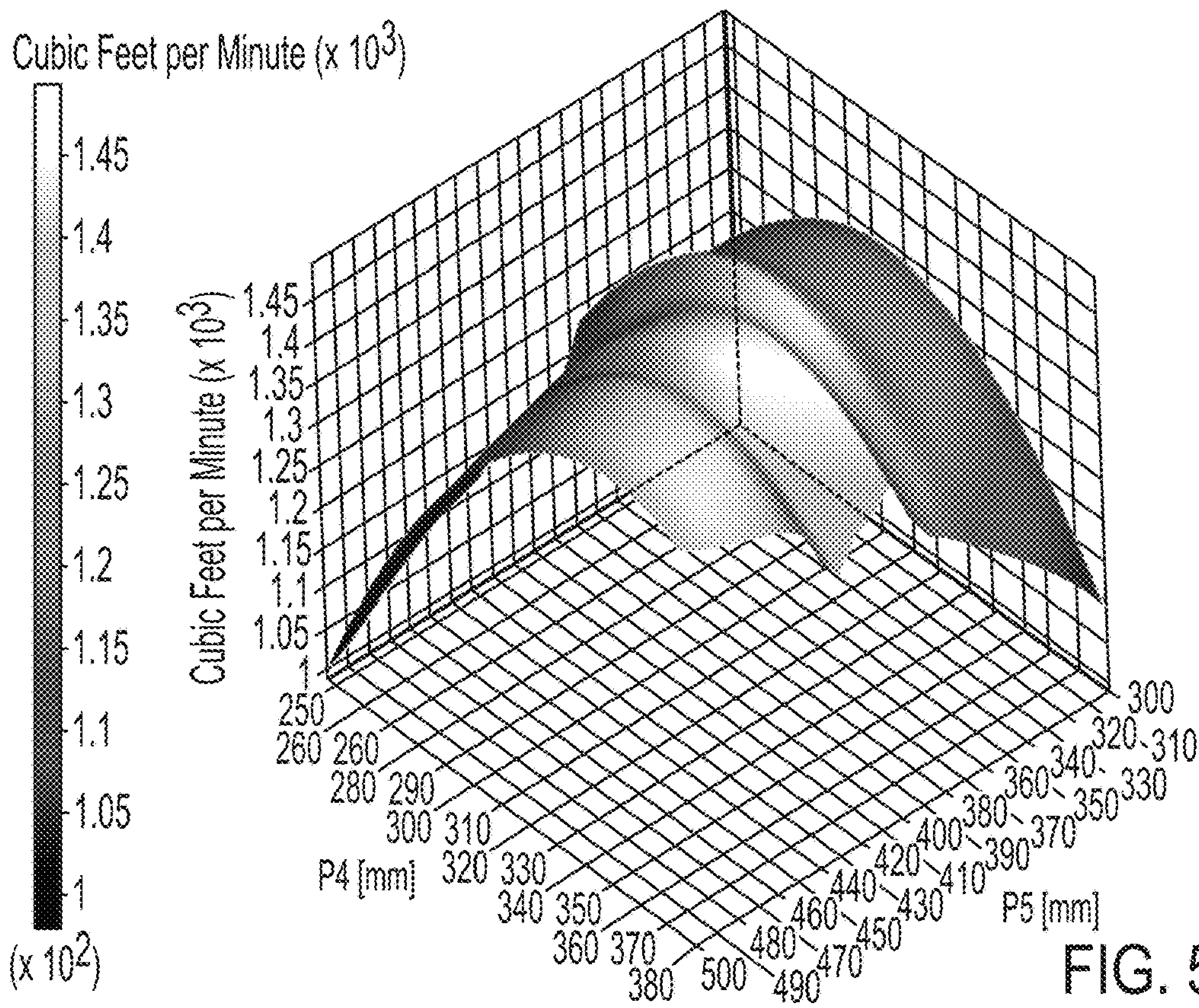

Cubic Feet per Minute (x 10^3)
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
(x 10^2)
Cubic Feet per Minute (x 10^3)
P4 [mm]
250
260
280
290
300
310
320
330
340
350
360
370
380
P5 [mm]
300
310
320
330
340
350
360
370
380
390
400
410
420
430
440
450
460
470
480
490
500

FIG. 5J

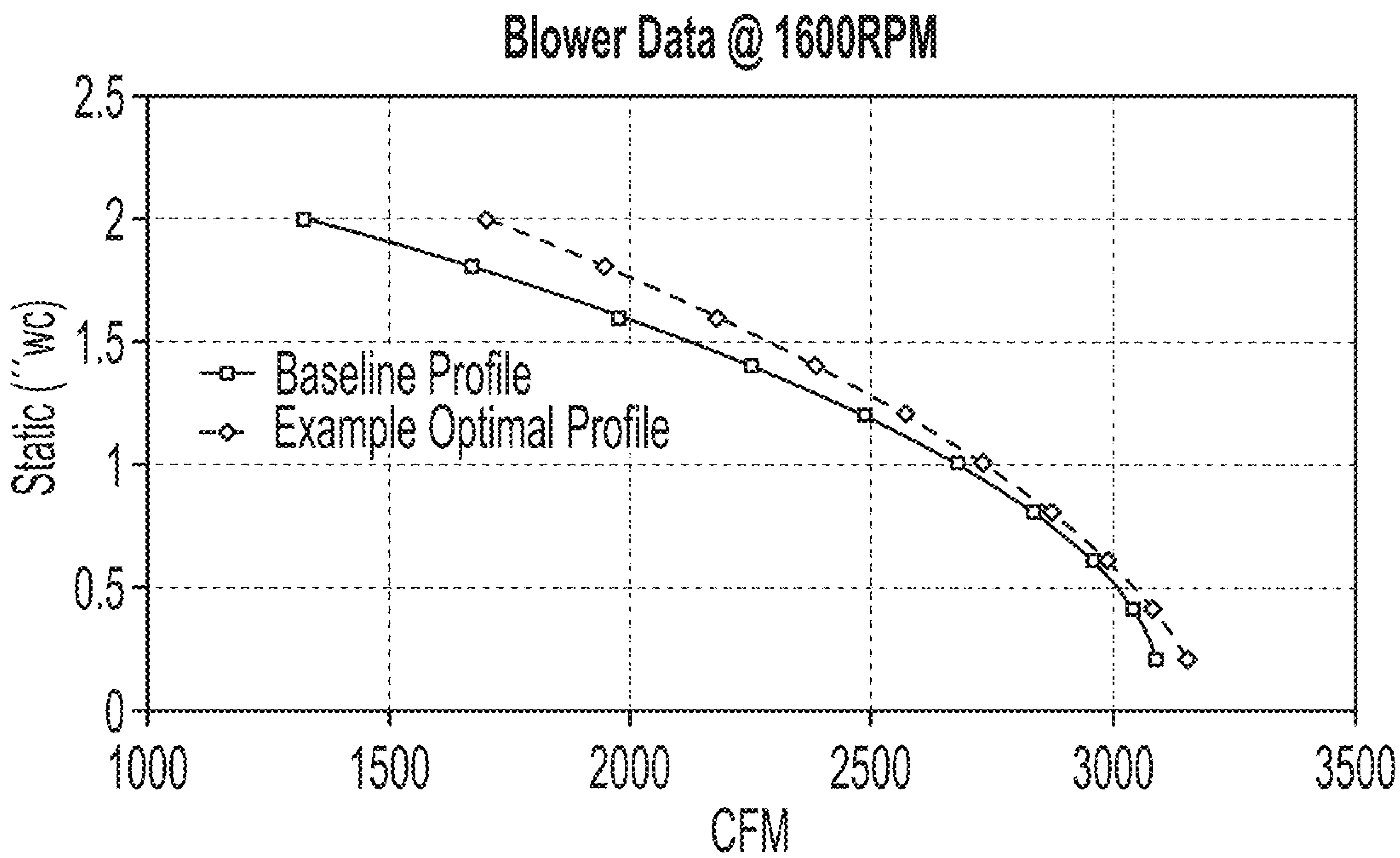

Blower Data @ 1600RPM
Static (''wc)
2.5
2
1.5
1
0.5
0
1000
1500
2000
2500
3000
3500
CFM
Baseline Profile
Example Optimal Profile

FIG. 6A

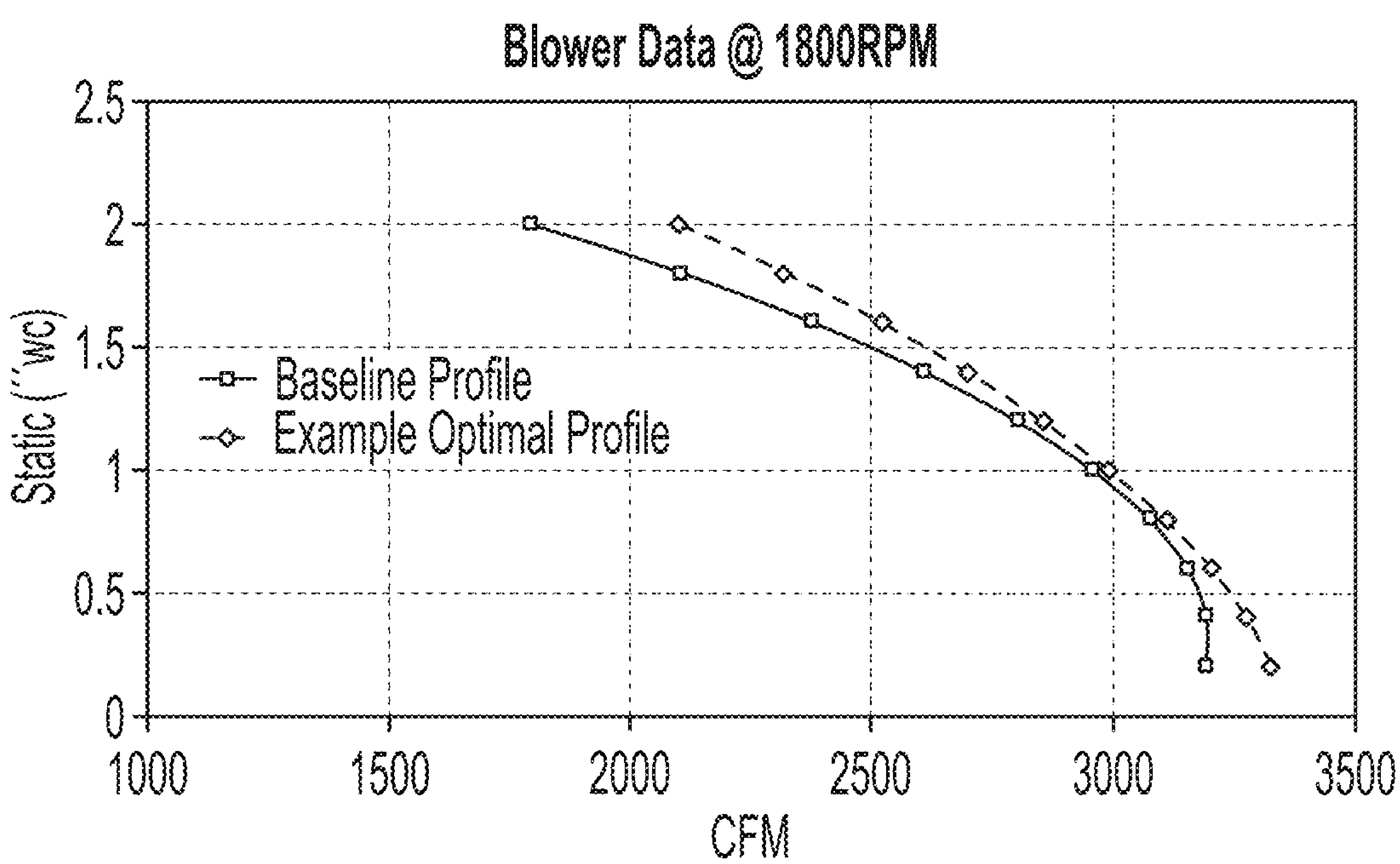

Blower Data @ 1800RPM
Static (''wc)
2.5
2
1.5
1
0.5
0
1000
1500
2000
2500
3000
3500
CFM
Baseline Profile
Example Optimal Profile

FIG. 6B

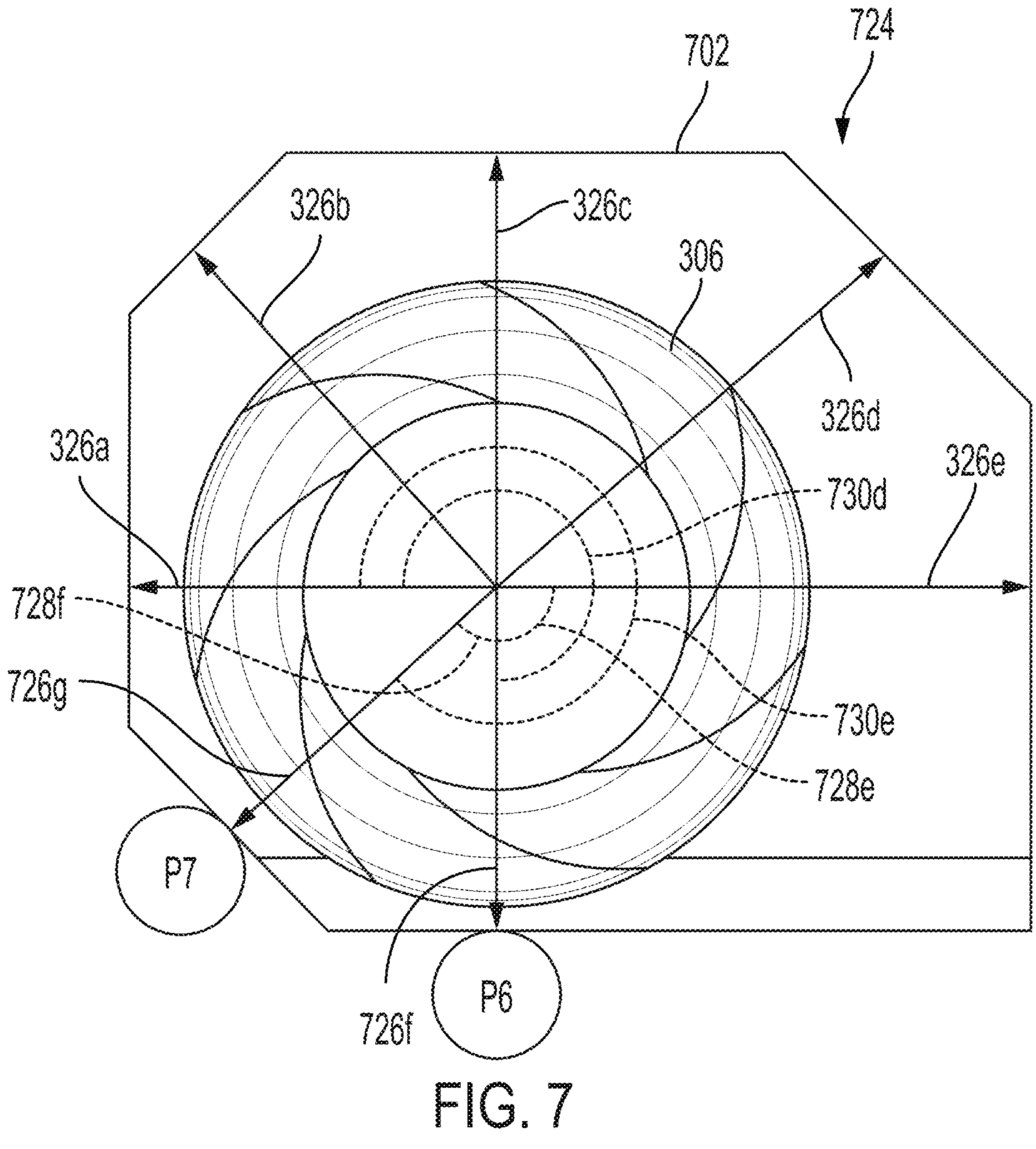

724
702
326b
326c
306
326d
326a
326e
730d
728f
726g
730e
728e
P7
P6
726f

FIG. 7

HIGH-PERFORMANCE HOUSINGS FOR BACKWARD-CURVED BLOWERS

TECHNICAL FIELD

The present disclosure relates generally to a heating, ventilation, and air conditioning (HVAC) system and more particularly, but not by way of limitation, to housings for backward-curved blowers.

BACKGROUND

HVAC systems include fans or blowers (e.g., that include blower wheels) that circulate air between the HVAC system and an enclosed space associated with the HVAC system. Some fans and blowers are designed to operate at different speeds so that conditioned air can be supplied to the enclosed space at different flow rates. For example, in multi-zone systems, less air flow is needed to supply one zone of the multi-zone system with conditioned air as compared to supplying conditioned air to two or more zones of the multi- zone system. The airflow from the fan or blower is varied by supplying the fan or blower with different amounts of power. For example, reducing the amount of power supplied to the fan or blower reduces the speed of the fan or blower and increasing the amount of power supplied to the fan or blower increases the speed of the fan or blower. While adjusting the amount of power supplied to the blower helps tailor the amount of airflow produced by the blower, increasing fan speed can result in operating conditions that are inefficient.

SUMMARY

In an embodiment, a blower for a heating, ventilation, and air conditioning system includes a blower wheel and a housing. The blower wheel includes backward-curved blades configured to rotate in a rotational plane. The housing forms an at least hexagonal cross-section around at least a portion of the rotational plane, where the blower wheel is positioned within the housing such that there exists a first distance and a second distance. The first distance is measured radially outward from a center of the blower wheel to a first side of the at least hexagonal cross-section. The second distance is measured radially outward from the center of the blower wheel to a second side of the at least hexagonal cross-section. The second distance forms a first angle with the first distance, the first angle being an acute angle. The first distance and the second distance are unequal and less than a diameter of the blower wheel.

In an embodiment, a method of assembling a blower includes providing a housing and a blower wheel. The blower wheel includes backward-curved blades configured to rotate in a rotational plane. The method also includes positioning the blower wheel in the housing such that the housing forms an at least hexagonal cross-section around at least a portion of the rotational plane and such that there exists a first distance and a second distance. The first distance is measured radially outward from a center of the blower wheel to a first side of the at least hexagonal cross-section. The second distance is measured radially outward from the center of the blower wheel to a second side of the at least hexagonal cross-section. The second distance forms a first angle with the first distance, the first angle being an acute angle. The first distance and the second distance are unequal and less than a diameter of the blower wheel.

In an embodiment, a heating, ventilation, and air conditioning system includes an evaporator coil and a blower coupled to the evaporator coil. The blower includes a blower wheel and a housing. The blower wheel includes backward-curved blades configured to rotate in a rotational plane. The housing forms an at least hexagonal cross-section around at least a portion of the rotational plane, where the blower wheel is positioned within the housing such that there exists a first distance and a second distance. The first distance is measured radially outward from a center of the blower wheel to a first side of the at least hexagonal cross-section. The second distance is measured radially outward from the center of the blower wheel to a second side of the at least hexagonal cross-section. The second distance forms a first angle with the first distance, the first angle being an acute angle. The first distance and the second distance are unequal and less than a diameter of the blower wheel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an illustrative HVAC system;

FIG. **2**A illustrates a perspective view of a blower;

FIG. **2**B illustrates a bottom view of a blower housing;

FIG. **2**C illustrates a cross-sectional view of blower wheel;

FIG. **3** illustrates a cross-sectional view of a blower **300** from an intake side thereof.

FIGS. **4**A-E are graphs illustrating simulated performance of a blower;

FIGS. **5**A-J are three-dimensional graphs illustrating simulated performance of a blower;

FIGS. **6**A-B are graphs illustrating simulated performance of a blower; and

FIG. **7** illustrates a cross-sectional view of a blower.

DETAILED DESCRIPTION

Embodiment(s) of the invention will now be described more fully with reference to the accompanying Drawings. The invention may, however, be embodied in many different forms and should not be construed as limited to the embodiment(s) set forth herein. The invention should only be considered limited by the claims as they now exist and the equivalents thereof.

FIG. **1** illustrates an HVAC system **100**. HVAC system **100** is configured to condition air via, for example, heating, cooling, humidifying, or dehumidifying air within an enclosed space **101**. In a typical embodiment, enclosed space **101** is, for example, a house, an office building, a warehouse, and the like. Thus, HVAC system **100** can be a residential system or a commercial system such as, for example, a rooftop system. HVAC system **100** includes various components; however, in other embodiments, HVAC system **100** may include additional components that are not illustrated but typically included within HVAC systems.

HVAC system **100** includes an indoor fan or blower **110**, a gas heat **103** typically associated with blower **110**, and an evaporator coil **120**, also typically associated with blower **110**. For the purposes of this disclosure, gas heat **103** is a single-stage gas furnace. HVAC system **100** includes an expansion valve **112**. Expansion valve **112** may be a thermal expansion valve or an electronic expansion valve. Blower **110**, gas heat **103**, expansion valve **112**, and evaporator coil **120** are collectively referred to as an indoor unit **102**. In a typical embodiment, indoor unit **102** is located within, or in close proximity to, enclosed space **101**. HVAC system **100** also includes a compressor **104**, an associated condenser coil **124**, and an associated condenser fan **115**, which are collectively referred to as an outdoor unit **106**. In various embodiments, outdoor unit **106** and indoor unit **102** are, for example, a rooftop unit or a ground-level unit. Compressor **104** and associated condenser coil **124** are connected to evaporator coil **120** by a refrigerant line **107**. Refrigerant line **107** includes, for example, a plurality of copper pipes that connect condenser coil **124** and compressor **104** to evaporator coil **120**. Compressor **104** may be, for example, a single-stage compressor, a multi-stage compressor, a single-speed compressor, or a variable-speed compressor. Blower **110** is configured to operate at different capacities (e.g., variable motor speeds) to circulate air through HVAC system **100**, whereby the circulated air is conditioned and supplied to enclosed space **101**. Blower **110** operates at different speeds depending on the demand. Blower **110** operates at lower speeds for lower demands and at higher speeds for higher demands. In some embodiments, indoor unit **102** includes a pressure sensor **111** that measures static pressure at an exit of blower **110**. Pressure sensor **111** may be any of a variety of pressure sensor types, such as a pressure transmitter, magnehelic gauge, and the like. Static pressure describes the air resistance that blower **110** operates against. The static pressure is the result of numerous aspects of the HVAC system, such as, for example, the size and length of the ductwork in the system. HVAC system **100** includes an expansion valve **112**. Expansion valve **112** may be a thermal expansion valve or an electronic expansion valve.

Still referring to FIG. **1**, HVAC system **100** includes an HVAC controller **170** configured to control operation of the various components of HVAC system **100** such as, for example, blower **110**, gas heat **103**, and compressor **104** to regulate the environment of enclosed space **101**. In some embodiments, HVAC system **100** can be a zoned system. HVAC system **100** includes a zone controller **172**, dampers **174**, and a plurality of environment sensors **176**. In a typical embodiment, HVAC controller **170** cooperates with zone controller **172** and dampers **174** to regulate the environment of enclosed space **101**.

HVAC controller **170** may be an integrated controller or a distributed controller that directs operation of HVAC system **100**. HVAC controller **170** includes an interface to receive, for example, thermostat calls, temperature setpoints, blower control signals, environmental conditions, and operating mode status for various zones of HVAC system **100**. The environmental conditions may include indoor temperature and relative humidity of enclosed space **101**. In a typical embodiment, HVAC controller **170** also includes a processor and a memory to direct operation of HVAC system **100** including, for example, a speed of blower **110**.

Still referring to FIG. **1**, in some embodiments, the plurality of environment sensors **176** are associated with HVAC controller **170** and also optionally associated with a user interface **178**. The plurality of environment sensors **176** provides environmental information within a zone or zones of enclosed space **101** such as, for example, temperature and/or humidity of enclosed space **101** to HVAC controller **170**. The plurality of environment sensors **176** may also send the environmental information to a display of user interface **178**. In some embodiments, user interface **178** provides additional functions such as, for example, operational, diagnostic, status message display, and a visual interface that allows at least one of an installer, a user, a support entity, and a service provider to perform actions with respect to HVAC system **100**. In some embodiments, user interface **178** is, for example, a thermostat. In other embodiments, user interface **178** is associated with at least one sensor of the plurality of environment sensors **176** to determine the environmental condition information and communicate that information to the user. User interface **178** may also include a display, buttons, a microphone, a speaker, or other components to communicate with the user. Additionally, user interface **178** may include a processor and memory configured to receive user-determined parameters such as, for example, a relative humidity of enclosed space **101** and to calculate operational parameters of HVAC system **100** as disclosed herein.

HVAC system **100** is configured to communicate with a plurality of devices such as, for example, a monitoring device **156**, a communication device **155**, and the like. In a typical embodiment, and as shown in FIG. **1**, monitoring device **156** is not part of HVAC system **100**. For example, monitoring device **156** is a server or computer of a third party such as, for example, a manufacturer, a support entity, a service provider, and the like. In some embodiments, monitoring device **156** is located at an office of, for example, the manufacturer, the support entity, the service provider, and the like.

In a typical embodiment, communication device **155** is a non-HVAC device having a primary function that is not associated with HVAC systems. For example, non- HVAC devices include mobile-computing devices configured to interact with HVAC system **100** to monitor and modify at least some of the operating parameters of HVAC system **100**. Mobile computing devices may be, for example, a personal computer (e.g., desktop or laptop), a tablet computer, a mobile device (e.g., smart phone), and the like. In a typical embodiment, communication device **155** includes at least one processor, memory, and a user interface such as a display. One skilled in the art will also understand that communication device **155** disclosed herein includes other components that are typically included in such devices including, for example, a power supply, a communications interface, and the like.

Zone controller **172** is configured to manage movement of conditioned air to designated zones of enclosed space **101**. Each of the designated zones includes at least one conditioning or demand unit such as, for example, gas heat **103** and user interface **178**, only one instance of user interface **178** being expressly shown in FIG. **1**, such as, for example, the thermostat. HVAC system **100** allows the user to independently control the temperature in the designated zones. In a typical embodiment, zone controller **172** operates dampers **174** to control air flow to the zones of enclosed space **101**.

A data bus **190**, which in the illustrated embodiment is a serial bus, couples various components of HVAC system **100** together such that data is communicated therebetween. Data bus **190** may include, for example, any combination of hardware, software embedded in a computer readable medium, or encoded logic incorporated in hardware or otherwise stored (e.g., firmware) to couple components of HVAC system **100** to each other. As an example and not by way of limitation, data bus **190** may include an Accelerated Graphics Port (AGP) or other graphics bus, a Controller Area Network (CAN) bus, a front-side bus (FSB), a HYPERTRANSPORT (HT) interconnect, an INFINIBAND interconnect, a low-pin-count (LPC) bus, a memory bus, a Micro Channel Architecture (MCA) bus, a Peripheral Component Interconnect (PCI) bus, a PCI-Express (PCI-X) bus, a serial advanced technology attachment (SATA) bus, a Video Electronics Standards Association local bus (VLB), or any other suitable bus or a combination of two or more of these. In various embodiments, data bus **190** may include any number, type, or configuration of data buses **190**, where appropriate. In particular embodiments, one or more data buses **190** (which may each include an address bus and a data bus) may couple HVAC controller **170** to other components of HVAC system **100**. In other embodiments, connections between various components of HVAC system **100** are wired. For example, conventional cable and contacts may be used to couple HVAC controller **170** to the various components. In some embodiments, a wireless connection is employed to provide at least some of the connections between components of HVAC system **100** such as, for example, a connection between HVAC controller **170** and blower **110** or the plurality of environment sensors **176**.

FIGS. **2**A-B illustrate a blower **200** having a housing **202**. In particular, FIG. **2**A illustrates a perspective view of blower **200**, while FIG. **2**B illustrates a bottom view of the housing **202**. Blower **200** may be incorporated into HVAC system **100** of FIG. **1**, for example, as blower **110**. With reference to FIGS. **2**A-B together, blower **200** includes the housing **202**, a motor **204**, and a blower wheel **206**. Motor **204** drives blower wheel **206**, which rotates in its rotational plane to draw air in through an intake **208** and push air out through an outlet **210** disposed on a bottom of housing **202**. In the illustrated embodiment, outlet **210** is shown to form a particular portion of the bottom of housing **202**. However, outlet **210** is shown with dashed lines in order to illustrate that, in various embodiments, a size and shape of outlet **210** can be configurable to suit a given implementation. For example, in some embodiments, outlet **210** can form an entirety of the bottom of housing **202**. In operation, air is pushed out through outlet **210** perpendicularly relative to a flow of air through intake **208**. Outlet **210** is coupled, for example, to gas heat **103** and evaporator coil **120**. In other aspects, gas heat **103** and evaporator coil **120** may be coupled to intake **208**. Air from blower **200** circulates through gas heat **103** and evaporator coil **120** for heating and cooling, respectively, as needed and then circulates through enclosed space **101**. Air from enclosed space **101** returns to indoor unit **102** via intake **208** of blower **200**.

FIG. **2**C illustrates a cross-sectional view of blower wheel **206**. As shown, blower wheel **206** includes backward-curved blades **212** that curve away from a direction **214** in which they rotate. For this reason, blower wheel **206** may be referred to as a backward- curved blower wheel and blower **200** may be referred to as a backward-curved blower. Backward-curved blades **212** each have a pressure side **216** and a suction side **218**. As the blower wheel rotates in the direction **214**, air exits the blower wheel **206** radially from each of the backward-curved blades **212**, for example, as illustrated by arrows **220** and **222**. Although three backward-curved blades **212** are labeled for simplicity, it should be appreciated that blower wheel **206** can include any suitable number of backward-curved blades **212**.

With reference to FIGS. **2**A-C collectively, blower **200** can be assembled in a fashion that improves overall blower efficiency. For example, housing **202** can be configurably manufactured such that, in cross-section relative to intake **208**, it forms a shape of five, six, seven or more sides, where the cross-section at least partially surrounds blower wheel **206** and its rotational plane. In certain embodiments, interior dimensions of housing **202** can be configured as a function of a diameter of blower wheel **206** so as to optimize performance benefits of the multi-sided cross section. Particular examples will be described relative to FIG. **3**.

FIG. **3** illustrates a cross-sectional view of a blower **300** from an intake side thereof. Blower **300** includes housing **302** and blower wheel **306**. In general, blower **300** and blower wheel **306** can operate as described relative to blower **200** and blower wheel **206**, respectively, of FIGS. **2**A-C. As illustrated, housing **302** forms cross-section **324** around at least a portion of a rotational plane of blower wheel **306**.

More particularly, FIG. **3** illustrates configurable distance parameters **326***a*, **326***b*, **326***c*, **326***d* and **326***e* (collectively, distance parameters **326**), which parameters are also referred to as P**1**, P**2**, P**3**, P**4** and P**5**, respectively. In the illustrated embodiment, cross-section **324** is a hexagonal shape such that distance parameters **326** each define a distance measured radially outward from a center of blower wheel **306** to a different side of the hexagonal shape. In addition, or alternatively, distance parameters **326** can be at least partially defined according to angles formed with each other in cross-section **324**. As described in greater detail below, blower **300** can be configurably manufactured and/or assembled in accordance with distance parameters **326**.

In the illustrated embodiment, distance parameters **326** form angles **328***a*, **328***b*, **328***c* and **328***d* (collectively, angles **328**) with each other. In particular, distance parameter **326***b* forms an angle **328***a* with distance parameter **326***a*, distance parameter **326***c* forms an angle **328***b* with distance parameter **326***b*, distance parameter **326***d* forms an angle **328***c* with distance parameter **326***c*, and distance parameter **326***e* forms an angle **328***d* with distance parameter **326***d*. It should be appreciated that distance parameters **326***b*, **326***c*, and **326***d* and **326***e* each form an angle with distance parameter **326***a*. As already stated, distance parameter **326***b* forms angle **328***a* with distance parameter **326***a*. Additionally, distance parameter **326***c* forms a cumulative angle **330***a* with distance parameter **326***a*, where cumulative angle **330***a* includes angles **328***a* and **328***b*. Similarly, distance parameter **326***d* forms a cumulative angle **330***b* with distance parameter **326***a*, where cumulative angle **330***b* includes angles **328***a*, **328***b* and **328***c*. In like fashion, distance parameter **326***e* forms a cumulative angle **330***c* with distance parameter **326***a*, where cumulative angle **330***c* includes angles **328***a*, **328***b*, **328***c* and **328***d*.

In some cases, angles **328** can each be acute angles of the same or different sizes. In one example, as illustrated in FIG. **3**, angles **328** can each be approximately 45 degrees. According to this example, cumulative angle **330***a* would be an approximately right angle (i.e., 90 degrees), cumulative angle **330***b* would be an obtuse angle of approximately 135 degrees, and cumulative angle **330***c* would be approximately 180 degrees. One skilled in the art will appreciate that all angles shown in FIG. **3** can be configurably sized to suit a given implementation.

In certain embodiments, distance parameters **326** can be configured as a function of a diameter of blower wheel **306**. In one example, distance parameters **326** can each define a distance approximately equal to a configurable value times the diameter of blower wheel **306**. In some embodiments, the configurable value that is multiplied by the diameter of blower wheel **306** can be less than one, such that distance parameters **326** are each a proportion of the diameter of blower wheel **306**. Table 1 below illustrates an example of ranges of values for distance parameters **326** as a function of the diameter of blower wheel **306**. Table 2 below illustrates a second example of ranges of values for distance parameters **326** as a function of the diameter of blower wheel **306**. In some embodiments, the narrower ranges of Table 2 produce performance improvements. Table 3 illustrates an example optimal profile for housing **302**, where a specific formula is listed for each of distance parameters **326**.

TABLE 1

Parameter	Minimum	Maximum
P1	0.55 * Diameter	0.7 * Diameter
P2	0.55 * Diameter	0.8 * Diameter
P3	0.55 * Diameter	0.8 * Diameter
P4	0.55 * Diameter	0.87 * Diameter
P5	0.7 * Diameter	1.14 * Diameter

TABLE 2

Parameter	Minimum	Maximum
P1	0.55 * Diameter	0.57 * Diameter
P2	0.73 * Diameter	0.75 * Diameter
P3	0.72 * Diameter	0.8 * Diameter
P4	0.84 * Diameter	0.86 * Diameter
P5	0.89 * Diameter	0.91 * Diameter

Example Optimal Profile

Parameter	Value
P1	0.55 * Diameter
P2	0.73 * Diameter
P3	0.72 * Diameter
P4	0.84 * Diameter
P5	0.89 * Diameter

FIGS. **4**A-E are graphs illustrating simulated performance of a blower, such as blower **300** of FIG. **3**, for different values of distance parameters **326**. FIGS. **4**A-E each depict performance in cubic feet per minute (CFM). With reference to FIG. **3** and Tables 1-3, FIGS. **4**A, **4**B, **4**C, **4**D, and **4**E correspond to P**1**, P**2**, P**3**, P**4**, and P**5**, respectively. The diameter can be any suitable value (e.g., 453 mm).

FIGS. **5**A-J are three-dimensional graphs illustrating simulated performance of an example blower, such as blower **300** of FIG. **3**, for different combinations of values of distance parameters **326**. FIGS. **5**A-J each depict performance in CFM. With reference to FIG. **3** and Tables 1-3, FIGS. **5**A, **5**B, **5**C and **5**D illustrate variation in performance for P**1** in combination with P**2**, P**1** in combination with P**3**, P**1** in combination with P**4**, and P**1** in combination with P**5**, respectively. FIGS. **5**E, **5**F and **5**G illustrate variation in performance for P**2** in combination with P**3**, P**2** in combination with P**4**, and P**2** in combination with P**5**, respectively. FIGS. **5**H and **5**I illustrate variation in performance for P**3** in combination with P**4** and for P**3** in combination with P**5**, respectively. FIG. **5**J illustrates variation in performance for P**4** in combination with P**5**.

FIGS. **6**A-B are graphs illustrating simulated performance of an example blower, such as blower **300** of FIG. **3**, operating at 1600 revolutions per minute (RPM) and 1800 RPM, respectively. More particularly, FIGS. **6**A-B each plot CFM versus static pressure (inches-water column) for each of a baseline housing profile and an example optimal housing profile. Generally, the baseline housing profile can correspond to an example housing profile that has not been optimized in the fashion described above relative to FIGS. **2**A-C and **3**. The example optimal housing profile can correspond to a housing profile that has been optimized, for example, according to Table 3 above. When FIGS. **4**A-E, **5**A-F, and **6**A-B are viewed in combination, it can be seen that a housing profile with the example optimal profile can provide, for example, improved flow at higher static pressure as compared, for example, to the housing **202** shown in FIG. **2**A.

FIG. **7** illustrates a cross-sectional view of a blower **700** from an intake side thereof. Blower **700** includes housing **702** and blower wheel **306** from FIG. **3**. As illustrated, housing **702** forms cross-section **724** around at least a portion of the rotational plane of blower wheel **306**.

More particularly, FIG. **7** illustrates distance parameters **326** from FIG. **3** along with distance parameters **726*f*** and **726*g*** (collectively, distance parameters **726**). Distance parameters **726*f*** and **726*g*** are also referred to as P**6** and P**7**, respectively. In contrast to the hexagonal shape of cross-section **324** of FIG. **3**, cross-section **724** is a heptagonal shape such that each individual distance parameter of distance parameters **326** and **726** defines a distance measured radially outward from the center of blower wheel **306** to a different side of the heptagonal shape. Blower **700** can be configurably manufactured and/or assembled in accordance with distance parameters **326** in combination with distance parameters **726**. In some embodiments, an outlet similar to outlet **210** can be disposed on a bottom of housing **702**, such that the bottom is entirely or partially open beginning at approximately P**6** and extending rightward to a right edge of the housing **702** and such that the bottom is closed from approximately P**6** and extending leftward to a left edge of housing **702**.

As with distance parameters **326**, distance parameters **726** can be at least partially defined according to angles that are formed in cross-section **724**. In the illustrated embodiment, distance parameter **726*f*** forms an angle **728*e*** with distance parameter **326*e*** while distance parameter **726*g*** forms an angle **728*f*** with distance parameter **726*f***. It should be appreciated that distance parameters **726*f*** and **726*g*** also each form an angle with distance parameter **326*a***. As shown, distance parameters **726*f*** and **726*g*** form cumulative angles **730*d*** and **730*e***, respectively, with distance parameter **326*a***.

Angles **728*e*** and **728*f*** can be, for example, angles of the same or different sizes. In the example of FIG. **7**, angle **728*e*** is shown to be an approximately right angle (i.e., 90 degrees) and angle **728*f*** is shown to be an acute angle of approximately 45 degrees. According to this example, cumulative angle **730*d*** would be approximately 270 degrees and cumulative angle **730*e*** would be approximately 315 degrees. One skilled in the art will appreciate that all angles shown in FIG. **7** can be configurably sized to suit a given implementation.

In similar fashion to the methods described relative to FIG. **3**, in certain embodiments, distance parameters **326** and **726** can be configured as a function of the diameter of blower wheel **306**. Table 4 below illustrates an example of ranges of values for distance parameters **326** and distance parameters **726** as a function of the diameter of blower wheel **306**. Table 5 illustrates an example optimal profile for housing **702**, where a specific formula is listed for each of distance parameters **326** and **726**.

Parameter	Minimum	Maximum
P1	0.55 * Diameter	0.57 * Diameter
P2	0.73 * Diameter	0.75 * Diameter
P3	0.72 * Diameter	0.8 * Diameter
P4	0.84 * Diameter	0.86 * Diameter
P5	0.89 * Diameter	0.91 * Diameter
P6	0.55 * Diameter	0.57 * Diameter

-continued

Parameter	Minimum	Maximum
P7	0.59 * Diameter	0.61 * Diameter

Example Optimal Profile	
Parameter	Value
P1	0.55 * Diameter
P2	0.73 * Diameter
P3	0.72 * Diameter
P4	0.84 * Diameter
P5	0.89 * Diameter
P6	0.55 * Diameter
P7	0.6 * Diameter

In this patent application, reference to encoded software may encompass one or more applications, bytecode, one or more computer programs, one or more executables, one or more instructions, logic, machine code, one or more scripts, or source code, and vice versa, where appropriate, that have been stored or encoded in a computer-readable storage medium. In particular embodiments, encoded software includes one or more application programming interfaces (APIs) stored or encoded in a computer-readable storage medium. Particular embodiments may use any suitable encoded software written or otherwise expressed in any suitable programming language or combination of programming languages stored or encoded in any suitable type or number of computer-readable storage media. In particular embodiments, encoded software may be expressed as source code or object code. In particular embodiments, encoded software is expressed in a higher-level programming language, such as, for example, C, Python, Java, or a suitable extension thereof. In particular embodiments, encoded software is expressed in a lower-level programming language, such as assembly language (or machine code). In particular embodiments, encoded software is expressed in JAVA. In particular embodiments, encoded software is expressed in Hyper Text Markup Language (HTML), Extensible Markup Language (XML), or other suitable markup language.

Depending on the embodiment, certain acts, events, or functions of any of the algorithms described herein can be performed in a different sequence, can be added, merged, or left out altogether (e.g., not all described acts or events are necessary for the practice of the algorithms) Moreover, in certain embodiments, acts or events can be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors or processor cores or on other parallel architectures, rather than sequentially. Although certain computer-implemented tasks are described as being performed by a particular entity, other embodiments are possible in which these tasks are performed by a different entity.

Conditional language used herein, such as, among others, "can," "might," "may," "e.g.," and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or states. Thus, such conditional language is not generally intended to imply that features, elements and/or states are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or states are included or are to be performed in any particular embodiment.

While the above detailed description has shown, described, and pointed out novel features as applied to various embodiments, it will be understood that various omissions, substitutions, and changes in the form and details of the devices or algorithms illustrated can be made without departing from the spirit of the disclosure. As will be recognized, the processes described herein can be embodied within a form that does not provide all of the features and benefits set forth herein, as some features can be used or practiced separately from others. The scope of protection is defined by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A blower for a heating, ventilation, and air conditioning system, the blower comprising:
- a blower wheel comprising backward-curved blades configured to rotate in a rotational plane;
- a housing forming a hexagonal cross-section around at least a portion of the rotational plane, wherein the blower wheel is positioned within the housing such that there exists:
  - a first distance measured radially outward from a center of the blower wheel to a first side of the hexagonal cross-section; and
  - a second distance measured radially outward from the center of the blower wheel to a second side of the hexagonal cross-section, wherein the second distance forms a first angle with the first distance, the first angle being an acute angle, and wherein the first distance and the second distance are unequal and less than a diameter of the blower wheel.

2. The blower of claim **1**, wherein the first angle is approximately 45 degrees.

3. The blower of claim **1**, wherein:
- the first distance is approximately 0.55 to 0.57 times the diameter of the blower wheel; and
- the second distance is approximately 0.73 to 0.75 times the diameter of the blower wheel.

4. The blower of claim **1**, wherein the blower wheel is positioned within the housing such that there exists a third distance measured radially outward from the center of the blower wheel to a third side of the hexagonal cross-section, wherein the third distance forms a second angle with the first distance, the second angle being an approximately right angle that includes the first angle.

5. The blower of claim **4**, wherein the third distance is approximately 0.72 to 0.8 times the diameter of the blower wheel.

6. The blower of claim **4**, wherein the blower wheel is positioned within the housing such that there exists a fourth distance measured radially outward from the center of the blower wheel to a fourth side of the hexagonal cross-section, wherein the fourth distance forms a third angle with the first distance, the third angle being an obtuse angle that includes the second angle.

7. The blower of claim **6**, wherein the fourth distance is approximately 0.84 to 0.86 times the diameter of the blower wheel.

8. The blower of claim **6**, wherein the third angle is approximately 135 degrees.

9. The blower of claim **6**, wherein the blower wheel is positioned within the housing such that there exists a fifth distance measured radially outward from the center of the blower wheel to a fifth side of the hexagonal cross-section, wherein the fifth distance forms a fourth angle with the first distance, and wherein the fourth angle is approximately 180 degrees and includes the third angle.

10. The blower of claim **9**, wherein the fifth distance is approximately 0.89 to 0.91 times the diameter of the blower wheel.

11. The blower of claim **9**, wherein:

the first distance is approximately 0.55 to 0.57 times the diameter of the blower wheel; and

the second distance is approximately 0.73 to 0.75 times the diameter of the blower wheel;

the third distance is approximately 0.72 to 0.8 times the diameter of the blower wheel;

the fourth distance is approximately 0.84 to 0.86 times the diameter of the blower wheel; and

the fifth distance is approximately 0.89 to 0.91 times the diameter of the blower wheel.

12. The blower of claim **9**, wherein the blower wheel is positioned within the housing such that there exists a sixth distance measured radially outward from the center of the blower wheel to a sixth side of the hexagonal cross-section, wherein the sixth distance forms a fifth angle with the first distance, and wherein the fifth angle includes the fourth angle.

13. The blower of claim **12**, wherein the fifth angle is approximately 270 degrees.

14. The blower of claim **12**, wherein the sixth distance is approximately 0.55 to 0.57 times the diameter of the blower wheel.

15. A method of assembling a blower, the method comprising:

providing a housing and a blower wheel, the blower wheel comprising backward-curved blades configured to rotate in a rotational plane; and

positioning the blower wheel in the housing such that the housing forms a hexagonal cross-section around at least a portion of the rotational plane and such that there exists:

a first distance measured radially outward from a center of the blower wheel to a first side of the hexagonal cross-section; and

a second distance measured radially outward from the center of the blower wheel to a second side of the hexagonal cross-section, wherein the second distance forms a first angle with the first distance, the first angle being an acute angle, and wherein the first distance and the second distance are unequal and less than a diameter of the blower wheel.

16. A heating, ventilation, and air conditioning system, comprising:

an evaporator coil;

a blower coupled to the evaporator coil, the blower comprising:

a blower wheel comprising backward-curved blades configured to rotate in a rotational plane;

a housing forming a hexagonal cross-section around at least a portion of the rotational plane, wherein the blower wheel is positioned within the housing such that there exists:

a first distance measured radially outward from a center of the blower wheel to a first side of the hexagonal cross-section; and

a second distance measured radially outward from the center of the blower wheel to a second side of the hexagonal cross-section, wherein the second distance forms a first angle with the first distance, the first angle being an acute angle, and wherein the first distance and the second distance are unequal and less than a diameter of the blower wheel.

* * * * *